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# Stereographic Projection in the Joint Surveillance System

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# STEREOGRAPHIC PROJECTION IN THE JOINT SURVEILLANCE SYSTEM

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large region. The results further indicate that the error can be corrected by a simple modification of the SAGE/ BUIC equations.

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## INTRODUCTION

In air defense and air traffic control systems, data from the system radars are stereographically projected onto a common coordinate plane for presentation to system operators. The stereographic projection of radar data involves two steps; stereographic projection using slant range, azimuth and height information to obtain polar coordinates in a plane of projection centered at the radar site, and transformation of the radar coordinates into cartesian coordinates on a common coordinate plane.

The stereographic projection and transformation process is mathematically complex. Because of the computational complexity, several assumptions and approximations have been made to expedite processing time without unduly sacrificing accuracy. The present SAGE/BUIC equations for computing radar coordinates, although satisfactory for their intended usage, introduce unacceptable registration errors when extended to large regions as will be encountered in the Joint Surveillance System (JSS).

This report describes analysis that was performed on the stereographic projection process. Equations for obtaining stereographic ground range are derived. The derivation indicates that the SAGE/BUIC ground range equation lacks a scale factor vital to proper registration in large regions. The scale factor is a function of the radius of the earth at a radar site and the radius of the conformal sphere.

## SECTION II

## EFFECT OF THE CONFORMAL SPHERE ON STEREOGRAPHIC PROJECTION

### STEREOGRAPHIC PROJECTION

Stereographic projection is a method for mapping points in space onto a plane tangent to a sphere. This sphere is termed the conformal sphere and its radius is arbitrary. Figure I depicts the projection geometry for a cross section of the sphere. The cross section is obtained by passing a plane through the center of the sphere, the aircraft, and the point of tangency. The intersection of this plane and the sphere is a great circle. Mapping of point A in space onto the tangent plane BB′ results in the stereographic ground range DT. DT is obtained by passing a line from point O, opposite the point of tangency D, through point P, the point of projection, and intersecting the tangent plane. Point P is the intersection of the line containing point A and the center of the earth, point C, and the great circle. If angle DCP is designated as $\psi$, then angle DOP equals $\psi/2$ since DC=CO=CP. The stereographic ground range DT is determined as follows.

$$DT = DO \tan\left(\frac{\psi}{2}\right) \tag{1}$$

If DT is defined as R and DC, CO, CP are defined as $E_c$, then equation (1) takes the form:

$$R = 2E_c \tan\left(\frac{\psi}{2}\right)$$

$$= 2E_c\left[\frac{1 - \cos\psi}{1 + \cos\psi}\right]^{1/2} \tag{2}$$

The stereographic ground range R is therefore directly proportional to the radius of the conformal sphere $E_c$.



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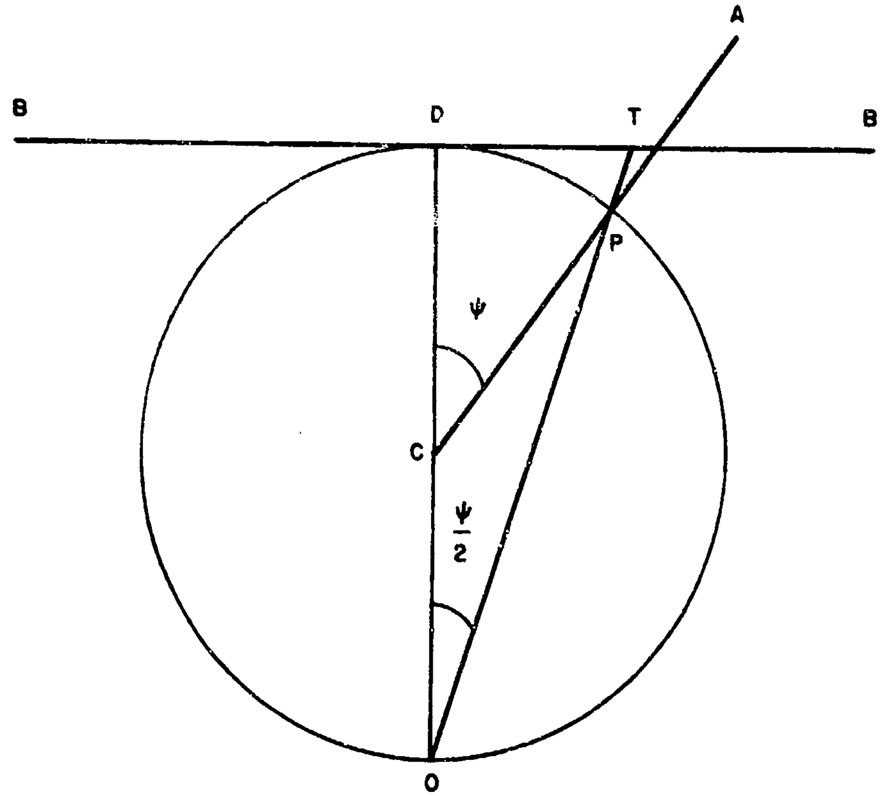


Figure I. STEREOGRAPHIC PROJECTION

## THE RADAR PLANE

Radar data are stereographically projected onto a plane centered at the reporting radar site and tangent to the conformal sphere. The plane will be termed the radar plane. The coordinate axes of the radar plane are oriented such that the positive Y axis is directed toward true north and the positive X axis towards east. Figure II shows the orientation of the coordinate axes on the radar plane. An aircraft's location on the plane is expressed in polar coordinates. The range R is the stereographic ground range, and the azimuth angle $\theta$ is the azimuth of the radar return. Azimuth angles are measured clockwise from the positive Y axis.

## DETERMINATION OF STEREOGRAPHIC GROUND RANGE

Radar slant range, height of the aircraft above sea level and elevation of the site above sea level are used to determine the stereographic ground range of an aircraft on the radar plane. The angle $\psi$ between the radar site, the center of the earth and the aircraft are used in equation (2) to calculate the stereographic ground range. The angle $\psi$ can be calculated if the earth is assumed to be spherical. Figure III illustrates the radar geometry for a cross section of a spherical earth where $E_s$ is the radius of the earth, h is the site elevation, S is the measured slant range and H is the aircraft height. From Figure III the angle $\psi$ may be calculated from the law of cosines.

$$S^2 = (E_s + h)^2 + (E_s + H)^2 - 2(E_s + h)(E_s + H)\cos\psi$$

$$\cos\psi = 1 + \frac{(H - h)^2 - S^2}{2(E_s + h)(E_s + H)}$$

$$= 1 - \frac{F^2}{2(E_s + h)(E_s + H)} \qquad (3)$$

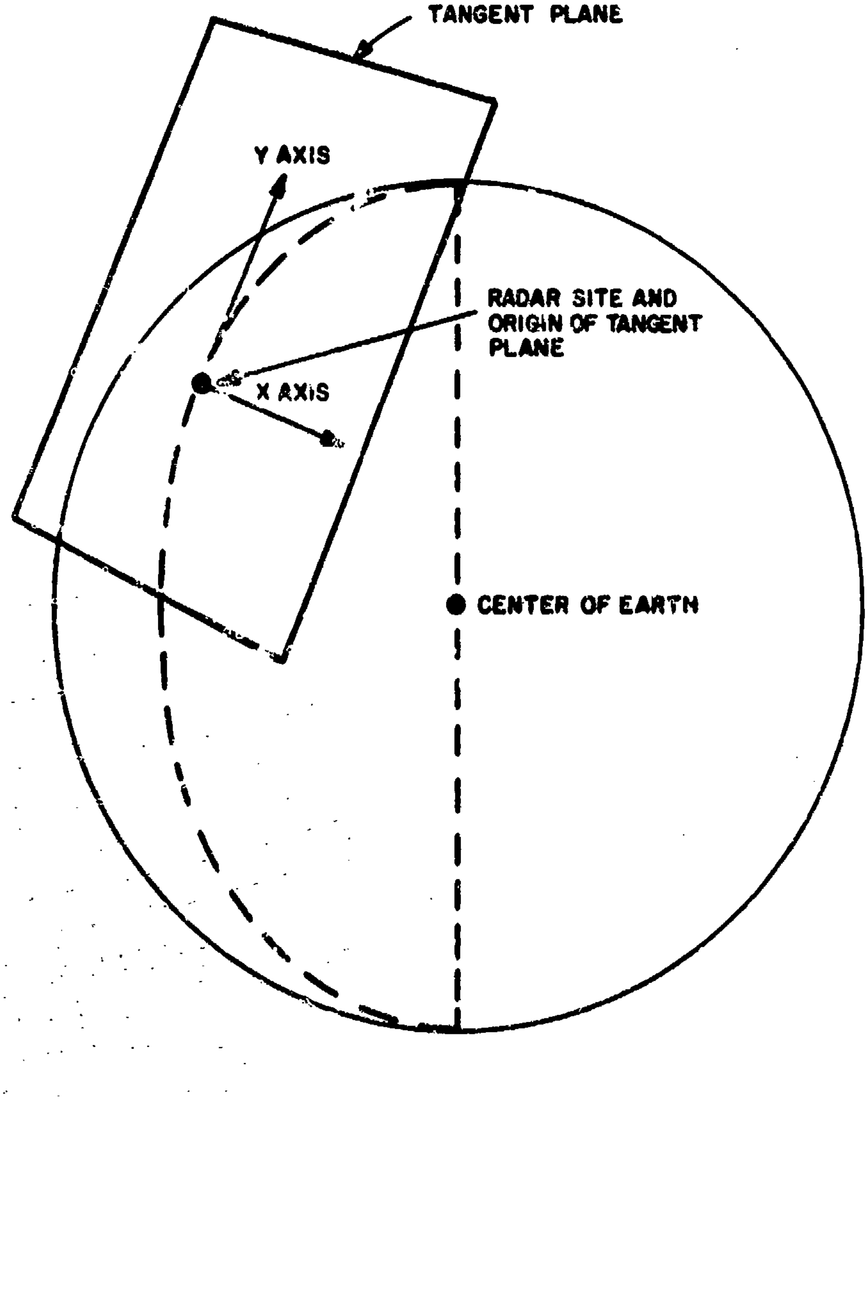


Figure II COORDINATE AXES ON RADAR PLANE

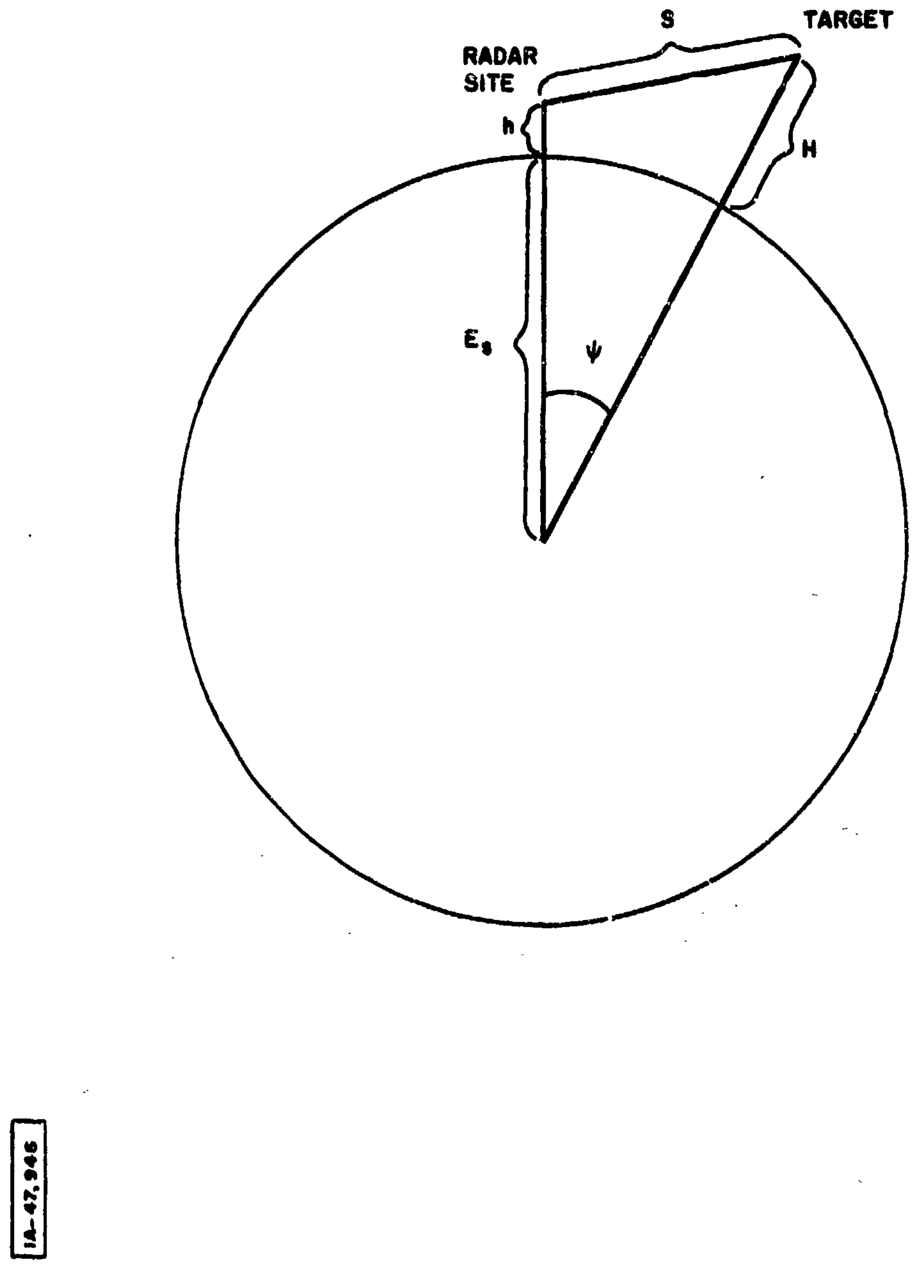


Figure III RADAR OBSERVATION GEOMETRY

where:

$$F^2 = S^2 - (H - h)^2$$

Substituting the results of equation (3) into equation (2), the ground range R may be obtained as follows.

$$R = 2E_c \left[ \frac{F^2}{4(E_s + h)(E_s + H) - F^2} \right]^{1/2}$$

$$= \frac{E_c F}{E_s} \left[ 1 + \frac{H + h}{E_s} + \frac{Hh}{E_s^2} - \frac{F^2}{4E_s^2} \right]^{-1/2} \qquad (4)$$

Reference 1 page 7 presents the SAGE/BUIC formulation of the ground range wherein it is assumed that $E_c$ and $E_s$ are equal and thus cancel. It will be shown that for the large regions that will be encountered in the JSS system, this assumption results in unacceptable registration errors.

## APPROXIMATIONS TO GROUND RANGE

The accuracy of typical common digitizer search radar outputs is 0.25 nmi in range and 0.18° in azimuth. Registration errors are a combination of data errors, radar site location errors, and errors due to approximations in the stereographic projection process. Since equation (4) is computationally complex, an approximation which does not unduly sacrifice accuracy is used to expedite processing time. A maximum error, induced by approximation, of 0.18 nmi provides a reasonable compromise between processing requirements and registration accuracy. Four approximations are presented in this section; the series approximation, the first order approximation, the JSS approximation and the current SAGE/BUIC approximation.

## The Series Approximation

Equation (4) may be written in the following form.

$$R \simeq \frac{E_c F}{E_s\left(1 + \frac{H + h}{E_s} + \frac{Hh}{E_s^2} - \frac{F^2}{4E_s^2}\right)^{1/2}} \tag{5}$$

The term within brackets in the denominator of equation (5) may then be expressed by the following series expansion.

$$(1 + x)^n = 1 + nx + \frac{n(n - 1)x^2}{2!} + \ldots$$

where:

$$x = \left(\frac{H + h}{E_s} + \frac{Hh}{E_s^2} - \frac{F^2}{4E_s^2}\right) \quad \text{and}$$

$$n = \frac{1}{2}$$

The maximum value of $x$ encountered in a JSS region is 0.005. Since $x << 1$, all but the first order term of the series may be ignored and equation (5) may be expressed as follows.

$$R \simeq \frac{E_c F}{E_s\left(1 + \frac{H + h}{2E_s} + \frac{Hh}{2E_s^2} - \frac{F^2}{8E_s^2}\right)} \tag{6}$$

## The First Order Approximation

The bracketed term in the demoninator of equation (6) contains a first order term and two second order terms. The maximum value of $\frac{H + h}{2E_s}$ is 0.00248, the maximum value of $\frac{hH}{2E_s^2}$ is 0.000000721, and the maximum value of $\frac{F^2}{8E_s^2}$ is 0.000424. Since the second order terms are smaller than the first order term, they may be neglected and equation (6) may be expressed as follows.

$$R = \frac{E_c F}{E_s\left(1 + \frac{H + h}{2E_s}\right)} \qquad (7)$$

The JSS Approximation

By replacing the aircraft height term (H) in the demoninator of equation (7) by a constant, equation (7) may be expressed as follows.

$$R = \frac{E_c F}{E_s\left(1 + \frac{(H_m/2) + h}{2E_s}\right)} \qquad (8)$$

where:

$H_m$ is the maximum expected aircraft altitude equal to 100,000 ft.

Equation (8) may be expressed in the following form.

$$R = CF$$

where:

$$C = \frac{E_c}{E_s\left(1 + \frac{(H_m/2) + h}{2E_s}\right)}$$

This is a particularly good approximation since the stereographic ground range is obtained from a simple scale multiplication of the quantity F. This greatly decreases the time required to process radar returns. The constant C is adaptation defined on a site-by-site basis.

The Current SAGE/BUIC Approximation

If $E_c$ is assumed to be the same as $E_s$, equation (8) is expressed as follows.

$$R = \frac{F}{\left(1 + \frac{(H_m/2) + h}{2E_s}\right)} \qquad (9)$$

## EARTH MODEL

The earth is not a perfect sphere. Therefore, for precise calculations of stereographic ground range, a model for the geometric shape of the earth must be adopted. An appropriate first order representation is an ellipsoid. The ellipsoid is generated by revolving an ellipse about its semiminor axis. The earth model can therefore be specified by its semimajor axis or equatorial radius $E_q$ and the eccentricity e. A cross section of the adopted earth model is shown in Figure IV. The eccentricity is defined as follows.

$$e^2 = 2f - f^2 \tag{10}$$

where:

$$f = \frac{E_q - E_p}{E_q}$$

$E_p$ is the semiminor axis or polar radius

The International Ellipsoid of 1924 will be used for the purpose of this report; thus, $E_q$ equals 3444.054 nmi and $e^2$ equals .00672267.

### Mapping from Ellipsoid to Sphere

The stereographic projection equations have been derived for a sphere. It is therefore necessary to transform points on or above the ellipsoid to points on or above the sphere. This transformation must be conformal, i.e., angle preserving, if the final stereographic projection is to be conformal. Reference 2 page 86 derives the relationship between the ellipsoid and the conformal sphere. The mapping of points on or above a location on the ellipsoid onto the conformal sphere is performed as follows.

$$\lambda' = \lambda$$

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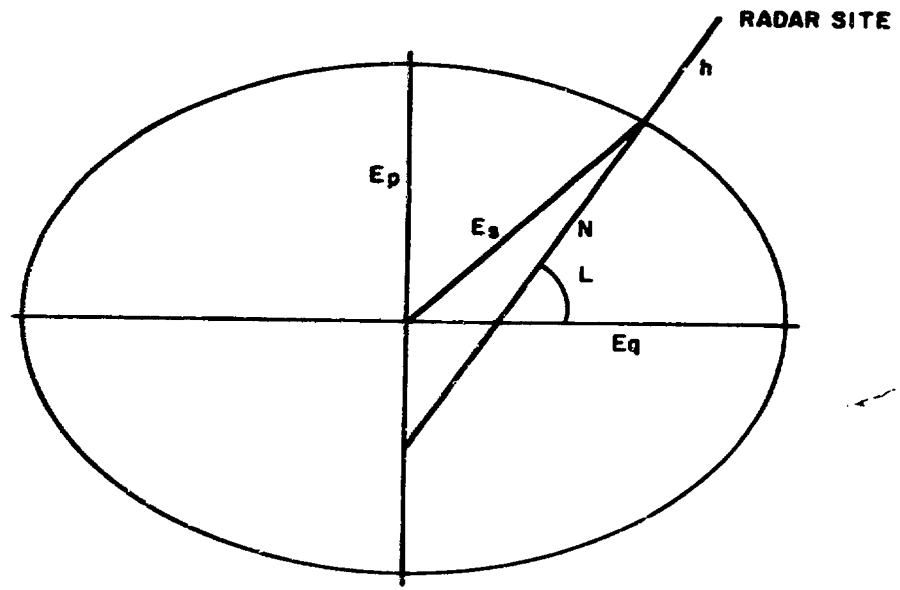


Figure IV A CROSS SECTION OF THE ADOPTED EARTH MODEL

$$\tan\left(\frac{\pi}{4} + \frac{\Phi}{2}\right) = \tan\left(\frac{\pi}{4} + \frac{L}{2}\right) \cdot \left[\frac{1 - e\sin L}{1 + e\sin L}\right]^{e/2} \tag{11}$$

In these equations:

$L, \lambda$ are the geographical latitude and longitude of the point on the ellipsoid

$\Phi, \lambda'$ are the latitude and longitude of the corresponding point on the conformal sphere. The latitude $\Phi$ is called the conformal latitude.

$e$ is the eccentricity of the earth.

Since the mapping process involves only a transformation of latitudes, the stereographic projection equations are valid for the ellipsoid if the conformal latitude ($\Phi$) is used in place of the geographic latitude (L).

Radius of the Earth to a Radar Site

In determination of the stereographic ground range, a spherical earth was used to compute the angle that subtends the radar site and the target. Since the earth is actually modeled by an ellipsoid, the use of a spherical earth in calculating stereographic ground range without introducing corrections to slant range and height, to allow for the conformal projection, will introduce a certain amount of error. To minimize this error, the radius of the spherical earth $E_s$ is set equal to the distance from the center of the ellipsoid to the surface of the ellipsoid at the radar site as shown in Figure IV. The distance $E_s$ is calculated as follows.

$$E_s = (X_2^2 + Y_s^2)^{1/2} \tag{12}$$

where:

$$X_s = N \cos L$$

$$Y_s = (1 - e^2)\, N \sin L$$

$$N = \frac{E_q}{(1 - e^2 \sin^2 L)^{1/2}}$$

L is the geographic latitude.

Table I gives the radius of the Earth at latitudes between 0 and 90 degrees.

Table I

Earth Radius Versus Latitude

| Geographic Latitude | Earth Radius (nmi) |
|---|---|
| 0° | 3444.054 |
| 10° | 3443.707 |
| 20° | 3442.708 |
| 30° | 3441.173 |
| 40° | 3439.286 |
| 50° | 3437.273 |
| 60° | 3435.375 |
| 70° | 3433.824 |
| 80° | 3432.810 |
| 90° | 3432.458 |

Calculations show that the resulting error is greatest for a target north or south of the radar and does not exceed ± 0.03 nmi at a range of 250 nmi.

THE COMMON COORDINATE PLANE

In a large air surveillance region such as will be encountered in the JSS, several radars are linked together in order to display a composite air surveillance picture. It is therefore necessary to transform coordinates on the individual radar planes to coordinates on a common plane. The transformation process requires that the coordinates of the radars on the common plane and that angular rotations between the radar planes and the common plane be known.

The origin of the common plane or region center is defined as the center of the smallest circle that will circumscribe all radars tied into the air surveillance region. The common plane is tangent to the conformal sphere. The coordinates axes are oriented such that the positive Y axis is directed towards true north and the positive X axis is directed towards east. Coordinates on the common plane are expressed in cartesian coordinates.

Radar Coordinates on the Common Plane

A radar site or other known location can be stereographically projected onto the common coordinate plane. Reference 3 page 53 derives the equations necessary to project a point on the conformal sphere onto the common coordinate plane. The rectangular coordinates of a radar site or other known location $X_r$, $Y_r$ on the common plane are obtained as follows.

$$X_r = 2E_c \frac{\sin\Delta\lambda\cos\phi}{1 + \sin\phi\sin\phi_0 + \cos\phi\cos\phi_0\cos\Delta\lambda} \tag{13}$$

$$Y_r = 2E_c \frac{\sin\phi\cos\phi_0 - \cos\phi\sin\phi_0\cos\Delta\lambda}{1 + \sin\phi\sin\phi_0 + \cos\phi\cos\phi_0\cos\Delta\lambda} \tag{14}$$

where:

| | |
|---|---|
| $\phi$, $\lambda$ | are the conformal latitude and longitude of the point to be projected |
| $\phi_0$, $\lambda_0$ | are the conformal latitude and longitude of the region center |
| $\Delta\lambda = \lambda_0 - \lambda$ | if longitudes are measured positive west of the prime meridian |
| $= \lambda - \lambda_0$ | if longitudes are measured positive east of the prime meridian |

## Angular Rotation

As indicated in reference 3 page 6, an angular rotation of the radar plane with respect to the common coordinate plane is necessary for the transformation process. The effect of the rotation is to make the axes of the radar plane more nearly parallel to the axes of the common plane. The angle of rotation is shown in reference 3 to be:

$$\beta = \tan^{-1}\left[\frac{-(\sin\phi + \sin\phi_0)\sin\Delta\lambda}{\cos\phi\cos\phi_0 + (1 + \sin\phi\sin\phi_0)\cos\Delta\lambda}\right] \tag{15}$$

## Transformation of Radar Coordinates on the Common Plane

The equations for transformation of radar coordinates to coordinates in the common coordinate plane are derived in reference 3 pages 3 - 15. The exact transformation equations involve an infinite series. To lessen the processing requirement without unduly sacrificing accuracy a second order approximation is used. Rectangular coordinates X, Y are obtained as follows.

$$X = X_r + K(R\sin(\theta + \beta) + AR^2\sin[2(\theta + \beta) - \gamma]) \tag{16}$$

$$Y = Y_r + K(R\cos(\theta + \beta) + AR^2\cos[2(\theta + \beta) - \gamma]) \tag{17}$$

where:

$$K = 1 + \frac{\omega_r^2}{4E_c^2}$$

$$A = \frac{\omega_r}{4E_c^2}$$

$$\omega_r = (X_r^2 + Y_r^2)^{1/2}$$

$$\gamma = \tan^{-1}\left(\frac{X_r}{Y_r}\right)$$

R is the stereographic ground range

$\theta$ is the azimuth angle measured clockwise from north at the radar site

$X_r$, $Y_r$ are the coordinates of the reporting radar on the common plane

Since the coordinates of an aircraft on the common plane are a function of the stereographic ground range R, any error in the stereographic ground range will appear as a misregistration on the common coordinate plane.

## THE CONFORMAL SPHERE

The common coordinate plane and all radar planes are tangent to the conformal sphere. The radius of the conformal sphere is arbitrary, but is chosen to minimize the scale errors that will be encountered in the air surveillance region. Scale errors result in mapping from the ellipsoid to the conformal sphere and in mapping from the conformal sphere onto the tangent plane.

### Scale Factor — Ellipsoid to Conformal Sphere

The scale factor associated with mapping from the ellipsoid to the conformal sphere is the ratio of a linear element on the conformal sphere to a corresponding linear element on the ellipsoid. From reference 2 page 86, the scale factor associated with a point of projection is:

$$k_1 = \frac{E_c \cos\phi}{N \cos L} \qquad (18)$$

where:

$\phi$ is the conformal latitude of the point to be projected

L is the geographic latitude of the point to be projected

The scale factor is a function of the radius of the conformal sphere and the conformal and geographic latitude of the point to be projected. The scale factor can be expressed as follows.

$$k_1 = \frac{E_c}{E_q} \frac{(1 - e^2 \sin^2 L)^{1/2} \cos\phi}{\cos L}$$

$$= \frac{E_c}{E_q} k_1' \tag{19}$$

Table II gives values of $k_1'$ for several different latitudes.

Table II

Scale Factor — Ellipsoid to Sphere versus Latitude

| Geographic Latitude | Scale Factor $k_1'$ |
|---|---|
| 0° | 1.00000000 |
| 10° | 1.00010071 |
| 20° | 1.00039099 |
| 30° | 1.00083667 |
| 40° | 1.00138493 |
| 50° | 1.00197024 |
| 60° | 1.00252203 |
| 70° | 1.00297314 |
| 80° | 1.00326821 |
| 90° | 1.00337838 |

## Scale Factor — Conformal Sphere to Plane

The scale factor associated with mapping from the conformal sphere to the plane of projection is the ratio of a linear element on the plane of projection to a corresponding linear element on the conformal sphere. The scale factor is therefore a function of the angular separation between the origin of the plane and the point of projection. The distance on the sphere between the origin of the plane and the point of projection is calculated as follows.

$$D = E_c \psi \tag{20}$$

The stereographic ground range R is given by equation (1) as follows.

$$R = 2E_c \tan\left(\frac{\psi}{2}\right) \tag{21}$$

The scale factor associated with mapping from the conformal sphere to the plane of projection is calculated as follows.

$$\begin{aligned} k_2 &= \frac{dR/_{d\psi}}{dD/_{d\psi}} \\ &= \sec^2\left(\frac{\psi}{2}\right) \\ &= \frac{2}{1 + \cos\psi} \end{aligned} \tag{22}$$

Table III presents the scale factor $k_2$ as a function of angular separation.

Table III

Scale Factor — Conformal Sphere to Plane versus Angular Separation

| Angular Separation | Scale Factor $k_2$ |
|---|---|
| 0° | 1.00000000 |
| 2° | 1.00030468 |
| 4° | 1.00121946 |
| 6° | 1.00274658 |
| 8° | 1.00488976 |
| 10° | 1.00765427 |
| 12° | 1.01104690 |
| 14° | 1.01507605 |
| 16° | 1.01975173 |
| 18° | 1.02508563 |
| 20° | 1.03109120 |

Aircraft and radar locations in the air surveillance region are presented on the common plane. The scale factor $k_2$, associated with the common plane is a function of the angular separation between the region center and the point of interest. From reference 3 page 23, the angular separation between the region center and a point of

interest can be expressed in terms of their locations on the conformal sphere as follows.

$$\cos\psi = \sin\phi\sin\phi_0 + \cos\phi\cos\phi_0\cos\Delta\lambda \tag{23}$$

Combining equations (22) and (23) the scale factor $k_2$ is expressed as follows.

$$k_2 = \frac{2}{1 + \sin\phi\sin\phi_0 + \cos\phi\cos\phi_0\cos\Delta\lambda} \tag{24}$$

<u>Calculation of the Radius of the Conformal Sphere</u>

The total scale factor in mapping a point from the ellipsoid to the common coordinate plane is the product of $k_1$ and $k_2$. The total scale factor is expressed as follows.

$$k = \frac{2E_c\cos\phi}{N\cos L(1 + \sin\phi\sin\phi_0 + \cos\phi\cos\phi_0\cos\Delta\lambda)} \tag{25}$$

The scale factor expresses the ratio of a linear element on the common coordinate plane to the corresponding element on the ellipsoid. The scale factor therefore represents the ratio of the velocity on the common plane to the corresponding velocity on the ellipsoid. A unity scale factor is highly desirable since velocity on the common plane will represent actual ground speed. The scale error is defined as the difference between the scale factor at a point in the region and a unity scale factor. The scale error $\varepsilon$ is expressed as follows.

$$\begin{aligned}\varepsilon &= \frac{2E_c\cos\phi}{N\cos L(1 + \sin\phi\sin\phi_0 + \cos\phi\cos\phi_0\cos\Delta\lambda)} - 1 \\ &= E_c A - 1\end{aligned} \tag{26}$$

The extent of an air surveillance region is defined by the location of the radars that are tied into it. Since the scale error varies as a function of the location and separation of a point from the region center, it is highly desirable to minimize the maximum scale

errors that will be encountered. From equation (26) the value of the scale error at a point can be varied by varying the radius of the conformal sphere $E_c$. It is therefore possible to obtain both positive and negative scale errors. To minimize the magnitude of the largest scale error, $E_c$ is chosen such that the magnitude of the maximum negative scale error is equal to the maximum positive scale error. The radius of the conformal sphere is obtained as follows.

$$\varepsilon_{min} + \varepsilon_{max} = 0$$

$$E_c A_{min} - 1 + E_c A_{max} - 1 = 0$$

$$E_c (A_{min} + A_{max}) - 2 = 0$$

$$E_c = \frac{2}{A_{min} + A_{max}} \tag{27}$$

where $A_{min}$ and $A_{max}$ are the smallest and largest A calculated for the region center and all radars tied to the region. Substituting equations (19) and (24) into equation (2<sup></sup>) the value of A may be calculated as follows.

$$A = \frac{k_1' k_2}{E_q} \tag{28}$$

The values of $A_{max}$ and $A_{min}$ for a given region can therefore be determined from Tables II and III. The following general conclusions can be drawn from examination of the tables.

1. $A_{min}$ usually corresponds to the region center since its value of $k_2$ is unity.
2. $A_{max}$ usually corresponds to the most distant radar since it has the largest angular separation. If two radars have the same angular separation, $A_{max}$ will correspond to the more northerly since it will have the larger $k_1$ value.

Table IV shows values of $E_c$ calculated for a region center at a geographic latitude of 45° and radar sites directly north and south of the region center. Table IV shows that the radius of the conformal sphere decreases markedly as the region size increases.

Table IV

$E_c$ Versus Region Size

| Geographic Latitude of Most Distant Radar | Distance From Region Center | $E_c$ |
|---|---|---|
| 47° | 120.012 | 3437.561 |
| 49° | 240.[illegible]10 | 3435.787 |
| 51° | 359.997 | 3435.963 |
| 53° | 479.970 | 3429.088 |
| 57° | 719.881 | 3418.170 |
| 61° | 959.744 | 3403.004 |
| 65° | 1199.563 | 3383.553 |
| 43° | 120.026 | 3437.964 |
| 41° | 240.064 | 3436.596 |
| 39° | 360.116 | 3434.179 |
| 37° | 480.179 | 3430.714 |
| 33° | 720.342 | 3420.628 |
| 29° | 960.553 | 3406.314 |
| 25° | 1200.808 | 3387.749 |

## Effect of $E_c/E_s$

The JSS stereographic ground range equation, equation (8), and the current SAGE/BUIC stereographic ground range equation, equation (9), differ by the scale factor $E_c/E_s$. The effect of $E_c/E_s$ can be expressed as the difference between the two equations as follows.

$$\delta = F\Big/\left(1 + \frac{H_{m/2} + h}{2E_s}\right)\left(1 - \frac{E_c}{E_s}\right)$$

$$= R\left(1 - \frac{E_c}{E_s}\right) \qquad (29)$$

Since stereographic ground range is transformed into coordinates on the common plane, a difference in the ground ranges will result in a corresponding misregistration on the common plane. The quantity R in equation (29) represents an approximation. Since the design registration error budget in JSS is .18 nmi, R must differ from its actual value by no more than .18 nmi. (A detailed review of the errors induced by an error in R is beyond the scope of this report.) Therefore a difference calculated by equation (29) greater than .36 nmi will guarantee an unacceptable registration error if the SAGE/BUIC stereographic ground range is used. To show the effect of $E_c/E_s$ as a function of region size, values of $\delta$ are shown in Table V for the radar locations, region center and values of $E_c$ indicated in Table IV. The value of R was arbitrarily chosen to be 100 and 200 nmi. Region size is defined as the distance of the most distant radar from the region center.

Table V

Difference Between Ground Range Equations 8 and 9 versus Region Size

| Geographic Latitude of Most Distant Radar | Approximate Region Size | $E_c/E_s$ | $\delta$ (nmi) R=100nmi | $\delta$ (nmi) R=200nmi |
|---|---|---|---|---|
| 47° | 120 | .9999 | .009 | .018 |
| 49° | 240 | .9995 | .049 | .098 |
| 51° | 360 | .9988 | .120 | .239 |
| 53° | 480 | .9978 | .221 | .442 |
| 57° | 720 | .9948 | .517 | 1.033 |
| 61° | 960 | .9906 | .937 | 1.875 |
| 65° | 1200 | .9852 | 1.485 | 2.969 |
| 43° | 120 | .9998 | .021 | .042 |
| 41° | 240 | .9993 | .072 | .145 |
| 39° | 360 | .9985 | .154 | .308 |
| 37° | 480 | .9973 | .266 | .533 |
| 33° | 720 | .9942 | .581 | 1.163 |
| 29° | 960 | .9898 | 1.018 | 2.036 |
| 25° | 1200 | .9842 | 1.576 | 3.152 |

Examination of Table V reveals that for R equal to 200 nmi, values of $\delta$ will exceed .36 nmi for regions somewhere between 360 nmi and 480 nmi. This indicates that the SAGE/BUIC stereographic ground range equation will produce unacceptable results in large regions. Some of the current SAGE/BUIC regions exceed these limits, and all JSS regions will exceed these limits by a considerable margin. Section III of this report is devoted to depicting the registration errors produced by the SAGE/BUIC and JSS stereographic ground range equations in the seven JSS regions.

## SECTION III

## EFFECT OF THE SAGE/BUIC AND JSS STEREOGRAPHIC GROUND RANGE EQUATIONS ON REGISTRATION

### INTRODUCTION

Accurate stereographic projection of radar data onto the common coordinate plane is vital to the operation of air defense and air traffic control systems. Large registration errors seriously downgrade the performance and stability of the active tracking algorithm. For each of the seven JSS regions, simulated radar data was used to demonstrate the effect of the SAGE/BUIC and JSS stereographic ground range equations on registration.

### SIMULATED RADAR DATA

Radar slant range and azimuth data were generated for four aircraft locations at altitudes of 30,000, 45,000 and 60,000 ft in each JSS region. Appendix I indicates the algorithm used to produce the data. For a particular radar, a slant range-azimuth pair was generated only if the aircraft was within 250 nmi of the radar and above the radar horizon. Aircraft locations were chosen so that slant ranges for the reporting radars would be greater than 170 nmi.

Radar slant ranges were converted into stereographic ground ranges using the SAGE/BUIC and JSS stereographic ground range equations (equations (8) and (9)). Stereographic ground ranges were transformed into coordinates on the common plane using equations (16) and (17). Since the location of the aircraft was known, actual coordinates on the common plane were computed using equations (13) and (14). The registration error was obtained by taking the magnitude of the difference between the actual coordinates on the common plane and those obtained by the SAGE/BUIC and JSS stereographic ground range equations.

Appendix II presents the data for the seven JSS regions. For each region, there is a Site Data, a Simulated Radar Data, and a Registration Error table. In addition there is a figure showing the location of the region center, radar sites, and aircraft. The following information is given in the tables.

Site Data Table:

1. Approximate geographic latitude and longitude of the region center and radar sites.
2. Radius of the earth to each radar site.
3. Coordinates on the common plane for each radar site.
4. The radius of the conformal sphere.

Simulated Radar Data Table:

1. The geographic latitude and longitude and altitude of the aircraft in the region.
2. The designation of all reporting radars.
3. Slant range and azimuth data for all reporting radars.

Registration Error Table:

1. Stereographic ground range calculated using the SAGE/BUIC and JSS ground range equations.
2. Coordinates on the common plane obtained from the SAGE/BUIC and JSS ground range equations.
3. Coordinates on the common plane obtained from the actual aircraft locations.
4. The registration error induced by the SAGE/BUIC and JSS ground range equations.

Examination of the tables in Appendix II reveals that use of the SAGE/BUIC stereographic ground range equation resulted in registration errors that exceeded the .18 nmi JSS registration error budget in all cases tested. Use of the JSS stereographic ground range equation resulted in acceptable registration errors. Table VI summarizes the

TABLE VI

WORST-CASE REGISTRATION ERRORS IN EACH JSS REGION

| JSS REGION | RADIUS OF THE CONFORMAL SPHERE | APPROXIMATE REGION SIZE (NM) | CASE # | SLANT RANGE (NM) | REGISTRATION ERRORS | |
|---|---|---|---|---|---|---|
| | | | | | SAGE/BUIC | JSS |
| NORTHEAST | 3428.842 | 507 | 12 | 179.161 | 0.584 | 0.016 |
| NORTHWEST | 3425.636 | 582 | 6 | 181.280 | 0.703 | 0.010 |
| SOUTHEAST | 3430.619 | 535 | 9 | 179.547 | 0.581 | 0.019 |
| SOUTHWEST | 3428.877 | 546 | 12 | 179.980 | 0.627 | 0.002 |
| EASTERN CANADA | 3411.221 | 844 | 12 | 179.475 | 1.433 | 0.015 |
| WESTERN CANADA | 3423.829 | 603 | 12a | 181.173 | 0.684 | 0.031 |
| ALASKAN | 3427.488 | 439 | 9 | 182.171 | 0.439 | 0.030 |

worst case results for slant ranges of approximately 180 nmi in each of the seven JSS regions.

The omission of the factor $E_c/E_s$ is responsible for the large registration errors produced by the SAGE/BUIC stereographic ground range equation. For a particular region, the value of $E_c$ is constant. The most southerly radar will have the largest value of $E_s$. Therefore the value of $\delta$ as calculated by equation (29) will be largest for the most southerly radar. This indicates that the worst case errors will be produced by the most southerly radar, and the best case errors by the most northerly. Further examination of Appendix II supports this conclusion.

## SECTION IV

## CONCLUSIONS

The scale factor $E_c/E_s$ should be included in the stereographic ground range equation to avoid large registration errors. This is especially important in large regions. The JSS stereographic ground range equation for processing returns with height data is:

$$R = \frac{E_c\left(S^2 - H^2\right)^{1/2}}{E_s\left(1 + \frac{H_m/2 + h}{2E_s}\right)}$$

The present SAGE/BUIC stereographic ground range equations should be modified to reflect the scale factor $E_c/E_s$. The modification would require a change in the adaptation parameters on a site-by-site basis.

## REFERENCES


1. J.J. Burke, An Improved Stereographic Coordinate Conversion Approximation for Radar Data Processing, MTR-2548, Contract F19628-73-C-0001, The MITRE Corporation, Bedford, MA, January 1973.

2. P. Thomas, Conformal Projections in Geodesy and Cartography, Special Publication 251, U.S. Coast and Geodetic Survey, 1952.

3. J.J. Burke, Stereographic Projection of Radar Data in a Netted Radar System, ESD-TR-73-210, AD 771544, November 1973.




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## APPENDIX I

## GENERATION OF SLANT RANGE AND AZIMUTH DATA

Radar slant range and azimuth data are calculated for aircraft locations using vector operations. The vector $\underline{V}$ from the center of the earth to a point on or above the ellipsoid is calculated as follows.

$$\underline{V} = \begin{cases} X_v = (N + H)\cos L\cos\lambda \\ Y_v = (N + H)\cos L\sin\lambda \\ Z_v = [N(1 - e^2) + H]\sin L \end{cases} \qquad \text{(A-1)}$$

where:

H is the height of the point above the ellipsoid

$\lambda$ is measured positive east of the prime meridian

The slant range S is computed as follows.

$$\underline{S} = \underline{T} - \underline{R}$$

$$S = |\underline{S}| \qquad \text{(A-2)}$$

where:

$\underline{T}$, $\underline{R}$ are vectors from the center of the earth to the aircraft and radar respectively.

The aircraft must be above the radar horizon for a radar return to be possible. The aircraft is above the radar horizon if:

$$\underline{S} \cdot \underline{Z} > 0$$

where:

$\underline{Z}$ is a unit vector directed along the zenith of the reporting radar as follows:



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$$\underline{Z} = \begin{cases} X_z = \cos L_r \cos\lambda_r \\ Y_z = \cos L_r \sin\lambda_r \\ Z_z = \sin L_r \end{cases} \tag{A-3}$$

$L_r$, $\lambda_r$ are the geographic latitude and longitude of the reporting radar

The azimuth angle $\theta$ is calculated as follows.

$$\theta = \tan^{-1}\left[\frac{\underline{S}\cdot\underline{E}}{\underline{S}\cdot\underline{N}}\right] \tag{A-4}$$

where:

$\underline{E}$ is a unit vector directed due east of the reporting radar as follows.

$$\underline{E} = \begin{cases} X_E = -\sin\lambda_r \\ Y_E = \cos\lambda_r \\ Z_E = 0 \end{cases} \tag{A-5}$$

$\underline{N}$ is a unit vector directed due north of the reporting radar as follows.

$$\underline{N} = \begin{cases} X_N = -\sin L_r \cos\lambda_r \\ Y_N = -\sin L_r \sin\lambda_r \\ Z_N = \cos L_r \end{cases} \tag{A-6}$$

## APPENDIX II

## SIMULATED DATA FOR THE SEVEN JSS REGIONS

Radar slant range and azimuth data were generated for four aircraft locations at altitudes of 30,000, 45,000 and 60,000 feet in each JSS region. For a particular radar, a slant range azimuth pair was generated if the aircraft was within 250 nmi of the radar and above the radar horizon. Radar slant ranges were converted into stereographic ground ranges using the SAGE/BUIC and JSS ground range equations. Stereographic ground ranges were transformed into coordinates on the common coordinate plane. The actual coordinates on the common plane were also obtained. The registration errors induced by the SAGE/BUIC and JSS ground range equations were calculated.

For each JSS region, there is a Site Data, Simulated Radar Data, and Registration Errors table. In addition, there is a figure showing radar site, aircraft, and region center locations.

### Explanation of Tables

The Site Data Table shows the following.

a) Approximate latitude and longitude of the radar sites and region center.

b) The earth radius to each radar site calculated using equation (12).

c) Coordinates on the common plane for the radar sites calculated using equations (13) and (14).

d) The radius of the conformal sphere calculated using equation (27).

The Simulated Radar Data Table shows the following.

a) The latitude, longitude and altitude of the aircraft.

b) The slant range and azimuth for all reporting radars. A

radar is a reporting radar if the target is within 250 nmi and above the radar horizon. Slant range and azimuth data are calculated using the algorithm in Appendix I.

The Registration Error Table shows the following.

a) The stereographic ground range calculated using the SAGE/BUIC and JSS ground range equations (equations (8) and (9)).

b) Coordinates on the common plane obtained from the SAGE/BUIC and JSS stereographic ground range equations using equations (16) and (17).

c) Coordinates on the common plane obtained from the actual location of the aircraft using equations (13) and (14).

d) The registration error induced by the SAGE/BUIC and JSS stereographic ground range equations.

TABLE BI

SITE DATA - NORTHEAST JSS REGION

| SITE # | SITE LOCATION | | | EARTH RADIUS TO SITE | COORDINATES ON THE COMMON PLANE | |
|---|---|---|---|---|---|---|
| | DESIGNATION | APPROXIMATE LATITUDE | APPROXIMATE LONGITUDE | $E_s$ | X | Y |
| 1 | BENSON, NC | 35.4 | 78.6 | 3440.184 | 93.379 | -495.951 |
| 2 | BOSTON, MA | 42.4 | 71.7 | 3438.806 | 416.372 | -54.479 |
| 3 | BUCKS HARBOR, ME | 44.6 | 68.8 | 3438.361 | 499.454 | 89.369 |
| 4 | CLEVELAND, OH | 41.5 | 81.7 | 3438.987 | -53.965 | -131.216 |
| 5 | DETROIT, MI | 42.3 | 83.1 | 3438.826 | -115.445 | -81.965 |
| 6 | DUBOIS, PA | 41.1 | 78.8 | 3439.067 | 76.925 | -154.757 |
| 7 | EMPIRE, MI | 44.8 | 86.1 | 3438.321 | -238.529 | 73.930 |
| 8 | FINLAND, MN | 47.4 | 91.3 | 3437.795 | -438.855 | 251.055 |
| 9 | HARTFORD, CT | 41.8 | 72.7 | 3438.926 | 348.913 | -97.562 |
| 10 | IVOR, VA | 36.9 | 76.9 | 3439.896 | 173.299 | -403.448 |
| 11 | NEW YORK, NY | 40.7 | 74.0 | 3439.147 | 295.843 | -168.207 |
| 12 | TREVOSE, PA | 40.1 | 75.0 | 3439.267 | 252.658 | -207.271 |
| 13 | UTICA, NY | 43.1 | 75.2 | 3438.665 | 232.255 | -28.533 |
| 14 | WASHINGTON, DC | 38.9 | 77.0 | 3439.505 | 163.712 | -283.874 |
| 15 | REGION CENTER | 43.7 | 80.5 | - | 0.000 | 0.000 |
| RADIUS OF THE CONFORMAL SPHERE = 3428.842 | | | | | | |

**TABLE BII**

**SIMULATED RADAR DATA - NORTHEAST JSS REGION**

| CASE # | AIRCRAFT LOCATION LATITUDE | AIRCRAFT LOCATION LONGITUDE | ALTITUDE (K-FT) | REPORTING RADAR(S) | SLANT RANGE (NM) | AZIMUTH |
|---|---|---|---|---|---|---|
| 1 | 50.0 | 89.1 | 30 | FINLAND, MN | 179.102 | 28.432 |
| 2 | 50.0 | 89.1 | 45 | FINLAND, MN | 179.251 | 28.432 |
| 3 | 50.0 | 89.1 | 60 | FINLAND, MN | 179.434 | 28.432 |
| 4 | 47.0 | 83.2 | 30 | EMPIRE, MI | 179.600 | 41.591 |
| 5 | 47.0 | 83.2 | 45 | EMPIRE, MI | 179.749 | 41.591 |
| 6 | 47.0 | 83.2 | 60 | EMPIRE, MI | 179.931 | 41.591 |
| 7 | 40.0 | 85.7 | 30 | DETROIT, MI | 178.666 | 220.236 |
| 8a<br>8b | 40.0 | 85.7 | 45 | DETROIT, MI<br>CLEVELAND, OH | 178.815<br>199.594 | 220.236<br>244.455 |
| 9a<br>9b | 40.0 | 85.7 | 60 | DETROIT, MI<br>CLEVELAND, OH | 178.998<br>199.772 | 220.236<br>244.455 |
| 10 | 34.0 | 81.8 | 30 | BENSON, NC | 179.315 | 243.007 |
| 11 | 34.0 | 81.8 | 45 | BENSON, NC | 179.464 | 243.007 |
| 12 | 34.0 | 81.8 | 60 | BENSON, NC | 179.647 | 243.007 |

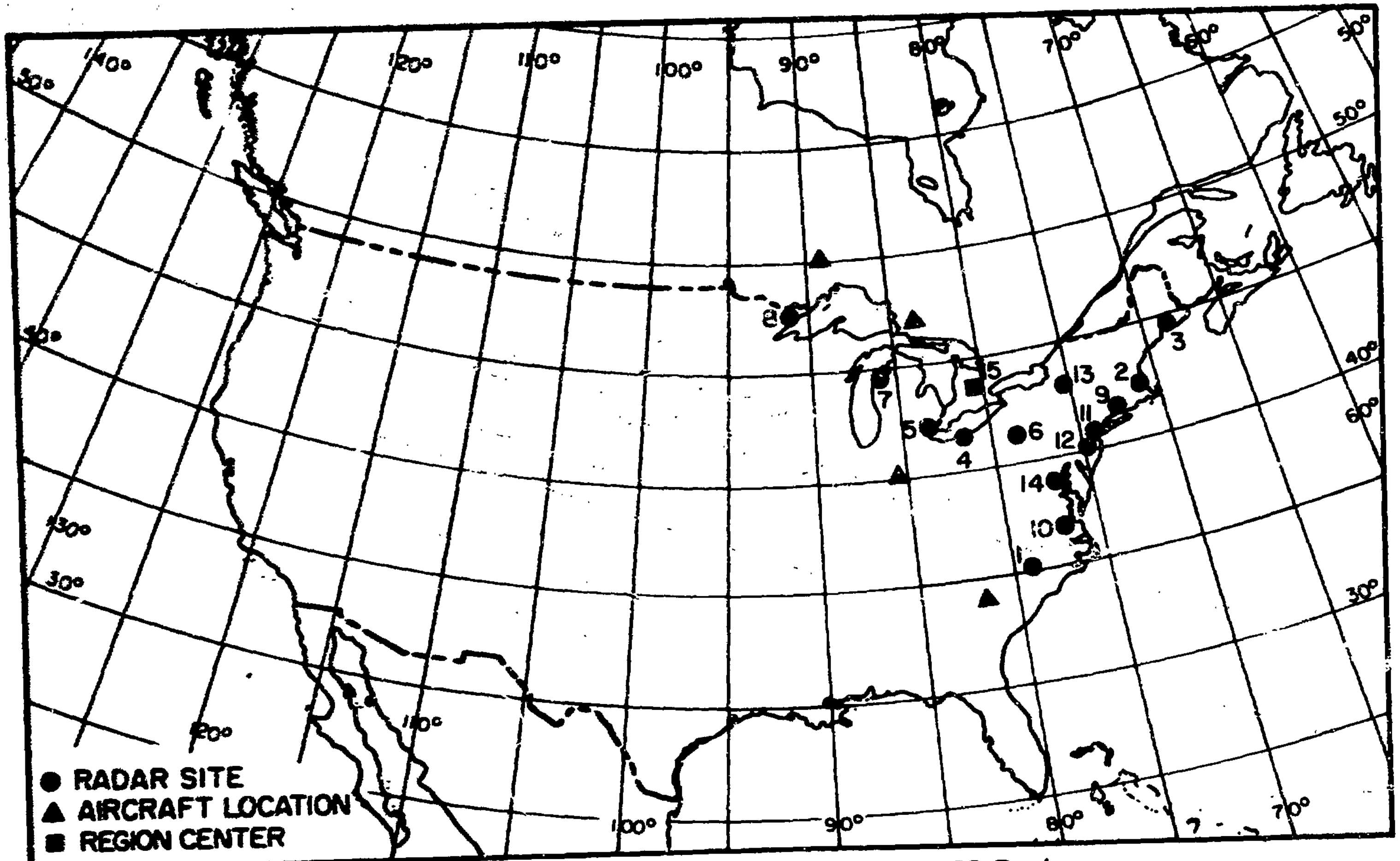


Fig. BI. Region Center, Radar Site, and Aircraft Locations – Northeast JSS Region

TABLE BIII

REGISTRATION ERRORS - NORTHEAST JSS REGION

| CASE # | STEREOGRAPHIC GROUND RANGE | | COORDINATES ON THE COMMON PLANE | | | | | | REGISTRATION ERROR (NM) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | BUIC/SAGE | | JSS | | ACTUAL | | | |
| | BUIC/SAGE | JSS | X | Y | X | Y | X | Y | BUIC/SAGE | JSS |
| 1 | 178.820 | 178.355 | -332.586 | 396.033 | -332.864 | 395.656 | -332.763 | 395.778 | 0.310 | 0.158 |
| 2 | 178.884 | 178.419 | -332.548 | 396.085 | -332.826 | 395.708 | -332.763 | 395.778 | 0.374 | 0.094 |
| 3 | 178.949 | 178.483 | -332.510 | 396.137 | -332.788 | 395.760 | -332.763 | 395.778 | 0.439 | 0.031 |
| 4 | 179.317 | 178.824 | -110.443 | 199.647 | -110.796 | 199.301 | -110.676 | 199.402 | 0.339 | 0.156 |
| 5 | 179.382 | 178.888 | -110.397 | 199.692 | -110.750 | 199.346 | -110.676 | 199.402 | 0.403 | 0.092 |
| 6 | 179.446 | 178.951 | -110.352 | 199.737 | -110.705 | 199.391 | -110.676 | 199.402 | 0.467 | 0.030 |
| 7 | 178.335 | 177.867 | -234.911 | -214.665 | -234.564 | -214.280 | -234.645 | -214.383 | 0.387 | 0.131 |
| 8a<br>8b | 178.448<br>199.219 | 177.931<br>198.632 | -234.953<br>-235.096 | -214.713<br>-214.574 | -234.607<br>-234.562 | -214.327<br>-214.328 | -234.645 | -214.383 | 0.451<br>0.490 | 0.068<br>0.099 |
| 9a<br>9b | 178.512<br>199.290 | 177.994<br>198.703 | -234.996<br>-235.161 | -214.760<br>-214.604 | -234.649<br>-234.627 | -214.375<br>-214.358 | -234.645 | -214.383 | 0.515<br>0.561 | 0.010<br>0.031 |
| 10 | 179.033 | 178.443 | -65.503 | -580.774 | -64.979 | -580.495 | -65.095 | -580.572 | 0.455 | 0.132 |
| 11 | 179.097 | 178.507 | -65.560 | -580.805 | -65.036 | -580.526 | -65.095 | -580.572 | 0.520 | 0.075 |
| 12 | 179.161 | 178.571 | -65.617 | -580.835 | -65.092 | -580.556 | -65.095 | -580.572 | 0.584 | 0.016 |

TABLE BIV

SITE DATA - NORTHWEST JSS REGION

| SITE # | SITE LOCATION | | | EARTH RADIUS TO SITE | COORDINATES ON THE COMMON PLANE | |
|---|---|---|---|---|---|---|
| | DESIGNATION | APPROXIMATE LATITUDE | APPROXIMATE LONGITUDE | $E_s$ | X | Y |
| 1 | BEACH, ND | 46.9 | 104.0 | 3437.896 | 311.418 | 122.482 |
| 2 | FINLEY, ND | 47.5 | 98.0 | 3437.775 | 550.135 | 190.838 |
| 3 | KALISPELL, MT | 48.2 | 114.0 | 3437.634 | -96.064 | 186.916 |
| 4 | KENO, OR | 42.1 | 121.9 | 3438.866 | -458.105 | -150.961 |
| 5 | KLAMATH, CA | 41.5 | 124.0 | 3438.987 | -556.568 | -173.879 |
| 6 | MAKAH, WA | 48.4 | 124.8 | 3437.594 | -525.023 | 241.556 |
| 7 | MALSTROM, MT | 47.8 | 111.2 | 3437.714 | 16.132 | 161.551 |
| 8 | MICA PEAK, WA | 47.5 | 117.0 | 3437.775 | -218.925 | 150.996 |
| 9 | SALEM, OR | 44.9 | 123.0 | 3438.301 | -483.632 | 22.063 |
| 10 | REGION CENTER | 45.1 | 111.6 | - | 0.000 | 0.000 |
| RADIUS OF THE CONFORMAL SPHERE = 3425.636 | | | | | | |

TABLE BV

SIMULATED RADAR DATA - NORTHWEST JSS REGION

| CASE # | AIRCRAFT LOCATION | | ALTITUDE (K-FT) | REPORTING RADAR(S) | SLANT RANGE(NM) | AZIMUTH |
|---|---|---|---|---|---|---|
| | LATITUDE | LONGITUDE | | | | |
| 1 | 50.0 | 128.7 | 30 | MAKAH, WA | 181.212 | 303.515 |
| 2 | 50.0 | 128.7 | 45 | MAKAH, WA | 181.361 | 303.515 |
| 3 | 50.0 | 128.7 | 60 | MAKAH, WA | 181.543 | 303.515 |
| 4 | 39.0 | 126.2 | 30 | KLAMATH, CA | 180.949 | 214.707 |
| 5 | 39.0 | 126.2 | 45 | KLAMATH, CA | 181.097 | 214.707 |
| 6 | 39.0 | 126.2 | 60 | KLAMATH, CA | 181.280 | 214.707 |
| 7 | 50.0 | 108.1 | 30 | MALMSTROM, MT | 180.466 | 41.732 |
| 8 | 50.0 | 108.1 | 45 | MALMSTROM, MT | 180.615 | 41.732 |
| 9a<br>9b | 50.0 | 108.1 | 60 | MALMSTROM, MT<br>BEACH, ND | 180.797<br>248.353 | 41.732<br>320.177 |
| 10 | 50.0 | 95.5 | 30 | FINLEY, ND | 180.126 | 32.542 |
| 11 | 50.0 | 95.5 | 45 | FINLEY, ND | 180.275 | 32.542 |
| 12 | 50.0 | 95.5 | 60 | FINLEY, ND | 180.458 | 32.542 |

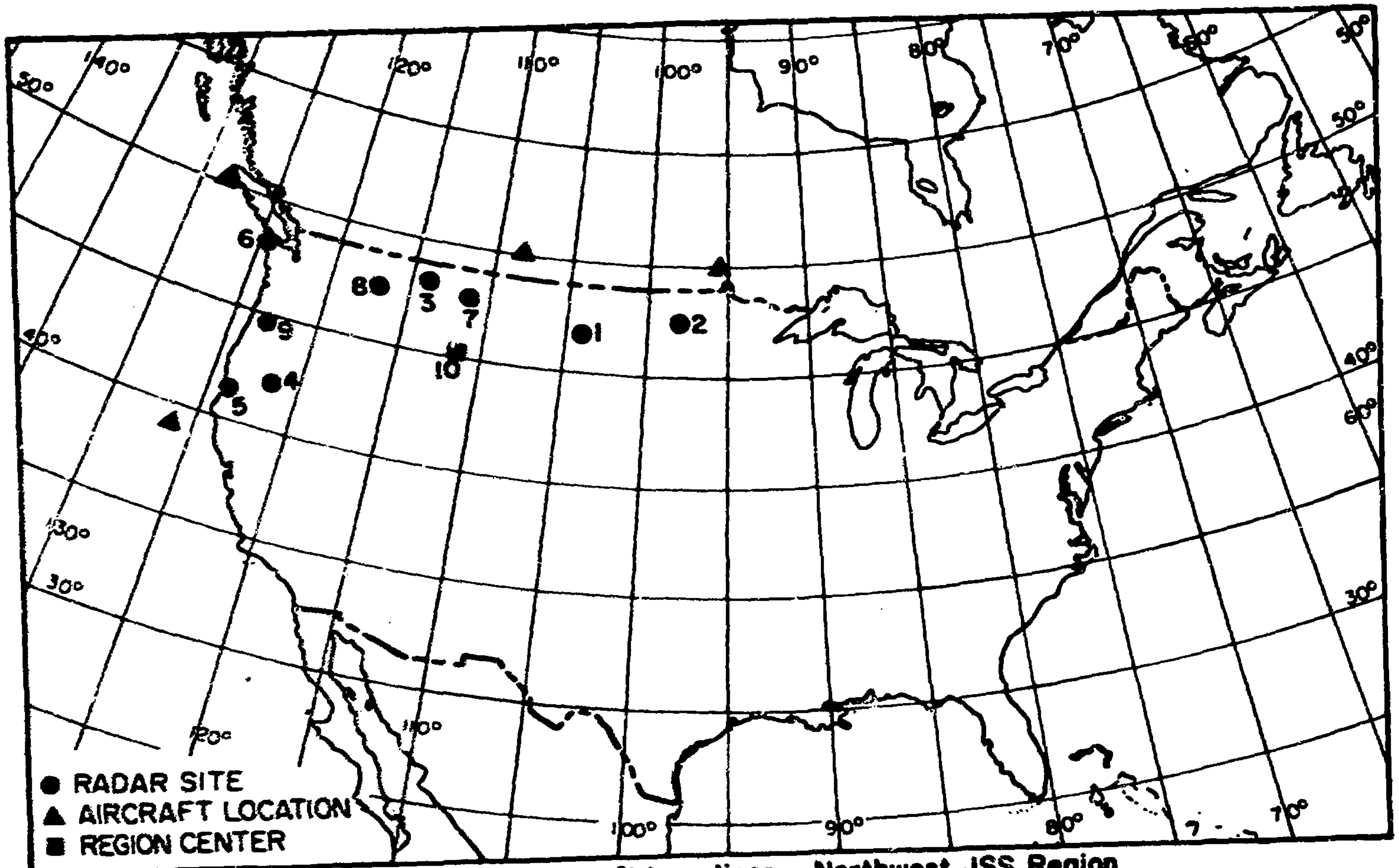

Fig. BII. Region Center, Radar Site, and Aircraft Locations – Northwest JSS Region

TABLE BVI

REGISTRATION ERRORS - NORTHWEST JSS REGION

| CASE # | STEREOGRAPHIC GROUND RANGE | | COORDINATES ON THE COMMON PLANE | | | | | | REGISTRATION ERROR (NM) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | BUIC/SAGE | | JSS | | ACTUAL | | | |
| | BUIC/SAGE | JSS | X | Y | X | Y | X | Y | BUIC/SAGE | JSS |
| 1 | 180.928 | 180.299 | -658.214 | 366.469 | -657.751 | 366.033 | -657.877 | 366.134 | .475 | 161 |
| 2 | 180.993 | 180.364 | -658.262 | 366.513 | -657.798 | 366.078 | -657.877 | 366.134 | .541 | .096 |
| 3 | 181.057 | 180.428 | -658.309 | 366.559 | -657.846 | 366.123 | -657.877 | 366.134 | .606 | .033 |
| 4 | 180.635 | 179.964 | -681.241 | -306.922 | -680.757 | -306.922 | -680.844 | -306.510 | .573 | .136 |
| 5 | 180.729 | 180.029 | -681.286 | -306.970 | -680.802 | -306.452 | -680.844 | -306.510 | .638 | .071 |
| 6 | 180.794 | 180.093 | -681.330 | -307.018 | -680.846 | -306.500 | -680.844 | -306.510 | .703 | .010 |
| 7 | 180.182 | 179.550 | 135.567 | 296.718 | 135.148 | 296.244 | 135.262 | 296.[illegible]53 | .476 | .158 |
| 8 | 180.247 | 179.614 | 135.610 | 296.767 | 135.190 | 296.292 | 135.262 | 296.353 | .541 | .094 |
| 9a<br>9b | 180.312<br>247.859 | 179.679<br>246.977 | 135.652<br>134.734 | 296.816<br>296.903 | 135.233<br>135.364 | 296.341<br>296.283 | 135.262 | 296.353 | .606<br>.762 | .031<br>.124 |
| 10 | 179.843 | 179.209 | 619.914 | 358.294 | 619.669 | 357.702 | 619.739 | 357.845 | .482 | .160 |
| 11 | 179.907 | 179.273 | 619.939 | 358.354 | 619.693 | 357.762 | 619.739 | 357.845 | .547 | .095 |
| 12 | 179.972 | 179.337 | 619.963 | 358.414 | 619.718 | 357.822 | 619.739 | 357.845 | .612 | .031 |

TABLE BVII

SITE DATA - SOUTHEAST JSS REGION

| SITE # | SITE LOCATION | | | EARTH RADIUS TO SITE | COORDINATES ON THE COMMON PLANE | |
|---|---|---|---|---|---|---|
| | DESIGNATION | APPROXIMATE LATITUDE | APPROXIMATE LONGITUDE | $E_s$ | X | Y |
| 1 | CROSS CITY, FL | 26.7 | 81.7 | 3441.729 | 402.130 | -142.802 |
| 2 | DAUPHIN ISLAND, AL | 30.3 | 88.1 | 3441.121 | 56.970 | 59.942 |
| 3 | ELLINGTON, TX | 29.6 | 95.2 | 3441.243 | -312.965 | 25.924 |
| 4 | GRAND BAY, AL | 30.5 | 86.4 | 3441.086 | 144.730 | 73.363 |
| 5 | JEDBERG, SC | 33.4 | 80.0 | 3440.561 | 461.596 | 264.072 |
| 6 | KEY WEST, FL | 24.6 | 82.0 | 3442.058 | 393.289 | -269.288 |
| 7 | LACKLAND, TX | 29.4 | 98.7 | 3441.277 | -496.689 | 26.093 |
| 8 | LAKE CHARLES, LA | 30.2 | 93.2 | 3441.138 | -207.382 | 57.280 |
| 9 | MACDILL, FL | 27.8 | 82.6 | 3441.548 | 350.265 | -79.885 |
| 10 | NEW ORLEANS, LA | 30.5 | 89.9 | 3441.086 | -36.178 | 71.718 |
| 11 | OILTON, TX | 27.8 | 99.2 | 3441.548 | -530.944 | -67.401 |
| 12 | PATRICK, FL | 28.6 | 80.7 | 3441.414 | 447.796 | -25.737 |
| 13 | RICHMOND, FL | 25.7 | 80.4 | 3441.888 | 476.194 | -197.948 |
| 14 | TYNDALL, FL | 30.1 | 85.6 | 3441.156 | 186.829 | 50.631 |
| 15 | WHITE HOUSE, FL | 29.9 | 81.8 | 3441.191 | 384.905 | 48.034 |
| 16 | REGION CENTER | 29.3 | 89.2 | - | 0.000 | 0.000 |
| RADIUS OF THE CONFORMAL SPHERE = 3430.619 | | | | | | |

TABLE BVIII

SIMULATED RADAR DATA – SOUTHEAST JSS REGION

| CASE # | AIRCRAFT LOCATION LATITUDE | AIRCRAFT LOCATION LONGITUDE | ALTITUDE (K-FT) | REPORTING RADAR(S) | SLANT RANGE (NM) | AZIMUTH |
|---|---|---|---|---|---|---|
| 1 | 33.0 | 76.5 | 30 | JEDBERG, SC | 178.009 | 96.780 |
| 2 | 33.0 | 76.5 | 45 | JEDBERG, SC | 178.158 | 96.780 |
| 3 | 33.0 | 76.5 | 60 | JEDBERG, SC | 178.341 | 96.780 |
| 4 | 28.0 | 77.4 | 30 | PATRICK, FL | 178.609 | 100.822 |
| 5a<br>5b | 28.0 | 77.4 | 45 | PATRICK, FL<br>RICHMOND, FL | 178.758<br>212.001 | 100.822<br>48.810 |
| 6a<br>6b<br>6c | 28.0 | 77.4 | 60 | PATRICK, FL<br>RICHMOND, FL<br>CROSS CITY, FL | 178.941<br>212.276<br>243.036 | 100.822<br>48.810<br>70.316 |
| 7 | 24.0 | 85.2 | 30 | KEY WEST, FL | 179.216 | 259.100 |
| 8 | 24.0 | 85.2 | 45 | KEY WEST, FL | 179.365 | 259.100 |
| 9 | 24.0 | 85.2 | 60 | KEY WEST, FL | 179.547 | 259.100 |
| 10 | 27.5 | 90.0 | 30 | NEW ORLEANS, LA | 179.798 | 181.704 |
| 11a<br>11b | 27.5 | 90.0 | 45 | NEW ORLEANS, LA<br>DAUPHIN IS., AL | 179.947<br>195.491 | 181.704<br>211.308 |
| 12a<br>12b<br>12c | 27.5 | 90.0 | 60 | NEW ORLEANS, LA<br>DAUPHIN IS., AL<br>LAKE CHARLES, LA | 180.130<br>195.670<br>234.010 | 181.704<br>211.308<br>132.999 |

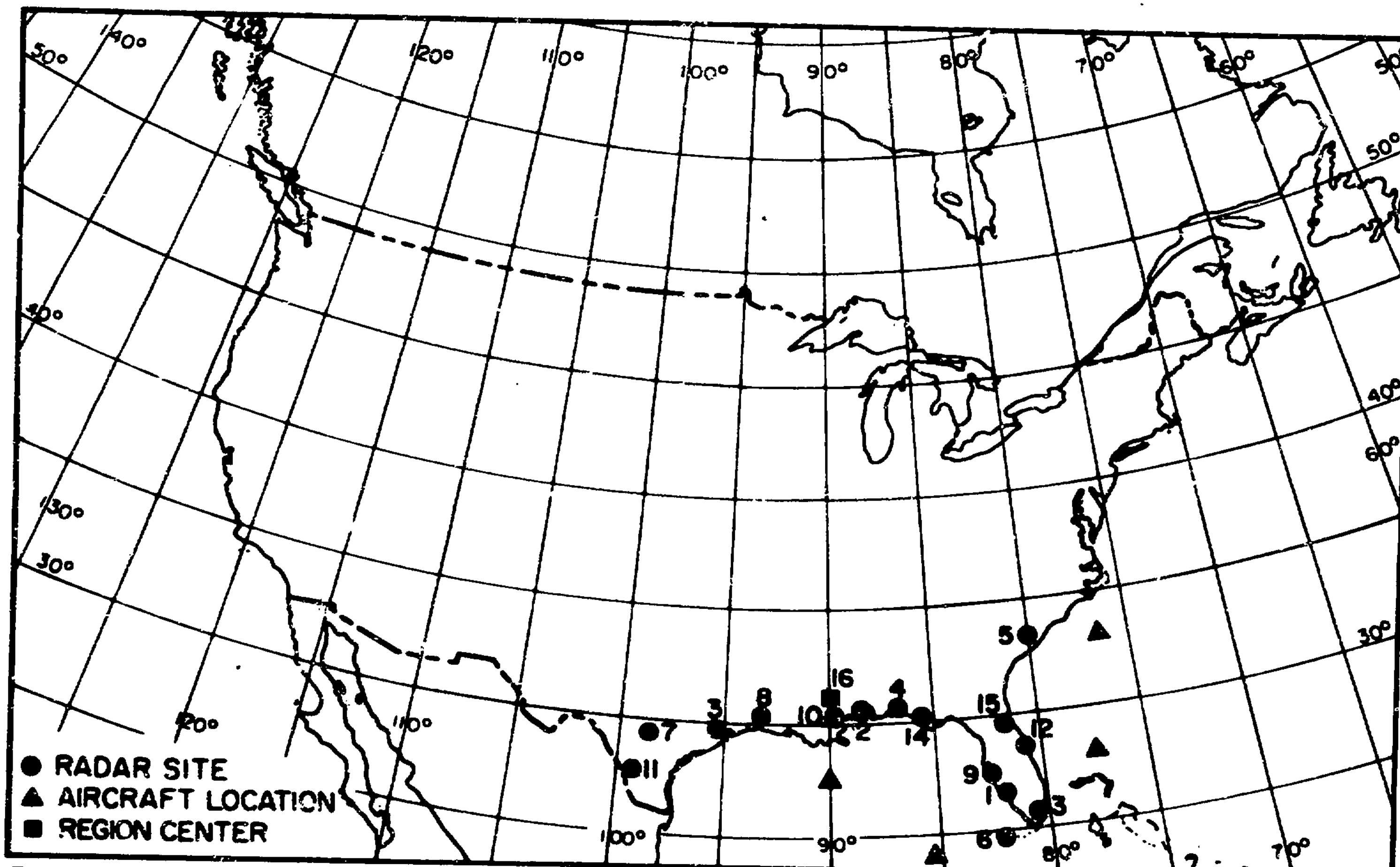

Fig. B III. Region Center, Radar Site and Aircraft Locations – Southeast JSS Region

TABLE XIX

REGISTRATION ERRORS - SOUTHEAST JSS REGION

| CASE # | STEREOGRAPHIC GROUND RANGE | | COORDINATES ON THE COMMON PLANE | | | | | | REGISTRATION ERROR (NM) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | BUIC/SAGE | | JSS | | ACTUAL | | | |
| | BUIC/SAGE | JSS | X | Y | X | Y | X | Y | BUIC/SAGE | JSS |
| 1 | 177.728 | 177.215 | 640.580 | 257.611 | 640.063 | 257.631 | 640.205 | 257.610 | .375 | .144 |
| 2 | 177.791 | 177.278 | 640.644 | 257.609 | 640.126 | 257.628 | 640.205 | 257.610 | .439 | .081 |
| 3 | 177.855 | 177.341 | 640.708 | 257.607 | 640.190 | 257.626 | 640.205 | 257.610 | .503 | .022 |
| 4 | 178.327 | 177.769 | 625.953 | -46.758 | 625.394 | -46.692 | 625.535 | -46.722 | .420 | .144 |
| 5a | 178.391 | 177.832 | 626.017 | -46.766 | 625.458 | -46.700 | 625.535 | -46.722 | .484 | .081 |
| 5b | 211.718 | 211.025 | 625.920 | -46.311 | 625.431 | -46.808 | | | .363 | .135 |
| 6a | 178.455 | 177.896 | 626.080 | -46.773 | 625.521 | -46.707 | 625.535 | -46.722 | .548 | .020 |
| 6b | 211.793 | 211.101 | 625.973 | -46.256 | 625.484 | -46.754 | | | .639 | .060 |
| 6c | 242.545 | 241.763 | 626.158 | -46.429 | 625.435 | -46.741 | | | .688 | .102 |
| 7 | 178.934 | 178.340 | 219.097 | -312.958 | 219.675 | -312.814 | 219.539 | -312.860 | .453 | .144 |
| 8 | 178.998 | 178.404 | 219.035 | -312.973 | 219.613 | -312.829 | 219.539 | -312.860 | .517 | .080 |
| 9 | 179.062 | 178.467 | 218.973 | -312.989 | 219.551 | -312.845 | 219.539 | -312.860 | .581 | .019 |
| 10 | 179.516 | 178.970 | -42.575 | -107.660 | -42.556 | -107.115 | -42.560 | -107.245 | .416 | .130 |
| 11a | 179.580 | 179.035 | -42.578 | -107.724 | -42.558 | -107.179 | -42.560 | -107.245 | .480 | .065 |
| 11b | 195.117 | 194.522 | -42.826 | -107.679 | -42.522 | -107.168 | | | .510 | .085 |
| 12a | 179.645 | 179.099 | -42.580 | -107.789 | -42.561 | -107.244 | -42.560 | -107.245 | .545 | .001 |
| 12b | 195.187 | 194.592 | -42.862 | -107.739 | -42.558 | -107.228 | | | .580 | .016 |
| 12c | 233.523 | 232.810 | -42.088 | -107.695 | -42.593 | -107.192 | | | .652 | .062 |

TABLE BX

SITE DATA – SOUTHWEST JSS REGION

| SITE # | SITE LOCATION | | | EARTH RADIUS TO SITE | COORDINATES ON THE COMMON PLANE | |
|---|---|---|---|---|---|---|
| | DESIGNATION | APPROXIMATE LATITUDE | APPROXIMATE LONGITUDE | $E_s$ | X | Y |
| 1 | EL PASO, TX | 31.8 | 105.9 | 3440.854 | 347.065 | -257.259 |
| 2 | LAKE HAVASU, AZ | 34.5 | 115.0 | 3440.355 | -113.710 | -106.173 |
| 3 | MT LAGUNA, CA | 32.8 | 116.4 | 3440.671 | -186.670 | -205.609 |
| 4 | OAKLAND, CA | 38.0 | 122.8 | 3439.682 | -477.514 | 126.934 |
| 5 | ODESSA, TX | 32.9 | 102.8 | 3440.653 | 498.919 | -178.606 |
| 6 | PASO ROBLES, CA | 36.0 | 120.5 | 3440.070 | -378.503 | -2.762 |
| 7 | PHOENIX, AZ | 33.5 | 112.1 | 3440.542 | 30.020 | -167.118 |
| 8 | POINT ARENA, CA | 38.9 | 123.7 | 3439.505 | -513.764 | 185.416 |
| 9 | SAN PEDRO, CA | 33.8 | 118.3 | 3440.486 | -279.209 | -141.482 |
| 10 | SILVER CITY, NM | 32.9 | 108.8 | 3440.653 | 196.527 | -199.258 |
| 11 | REGION CENTER | 36.3 | 112.7 | – | 0.000 | 0.000 |
| RADIUS OF THE CONFORMAL SPHERE = 3428.877 | | | | | | |

TABLE BXI

SIMULATED RADAR DATA - SOUTHWEST JSS REGION

| CASE # | AIRCRAFT LOCATION | | ALTITUDE (K-FT) | REPORTING RADAR(S) | SLANT RANGE (NM) | AZIMUTH |
|---|---|---|---|---|---|---|
| | LATITUDE | LONGITUDE | | | | |
| 1 | 39.0 | 127.5 | 30 | POINT ARENA, CA | 178.143 | 273.124 |
| 2 | 39.0 | 127.5 | 40 | POINT ARENA, CA | 178.292 | 273.124 |
| 3a<br>3b | 39.0 | 127.5 | 60 | POINT ARENA, CA<br>OAKLAND, CA | 178.475<br>229.828 | 273.124<br>286.604 |
| 4 | 34.0 | 123.2 | 30 | PASO ROBLES, CA | 179.237 | 228.788 |
| 5 | 34.0 | 123.2 | 45 | PASO ROBLES, CA | 179.386 | 228.787 |
| 6a<br>6b<br>6c | 34.0 | 123.2 | 60 | PASO ROBLES, CA<br>OAKLAND, CA<br>SAN PEDRO, CA | 179.569<br>240.948<br>245.494 | 228.787<br>184.764<br>274.168 |
| 7 | 30.0 | 117.7 | 30 | MT LAGUNA, CA | 180.610 | 202.056 |
| 8 | 30.0 | 117.7 | 45 | MT LAGUNA, CA | 180.759 | 202.056 |
| 9a<br>9b | 30.0 | 117.7 | 60 | MT LAGUNA, CA<br>SAN PEDRO, CA | 180.942<br>230.076 | 202.056<br>172.168 |
| 10 | 28.8 | 106.0 | 30 | EL PASO, TX | 179.830 | 181.682 |
| 11 | 28.8 | 106.0 | 45 | EL PASO, TX | 179.980 | 181.682 |
| 12 | 28.8 | 106.0 | 60 | EL PASO, TX | 179.980 | 181.682 |

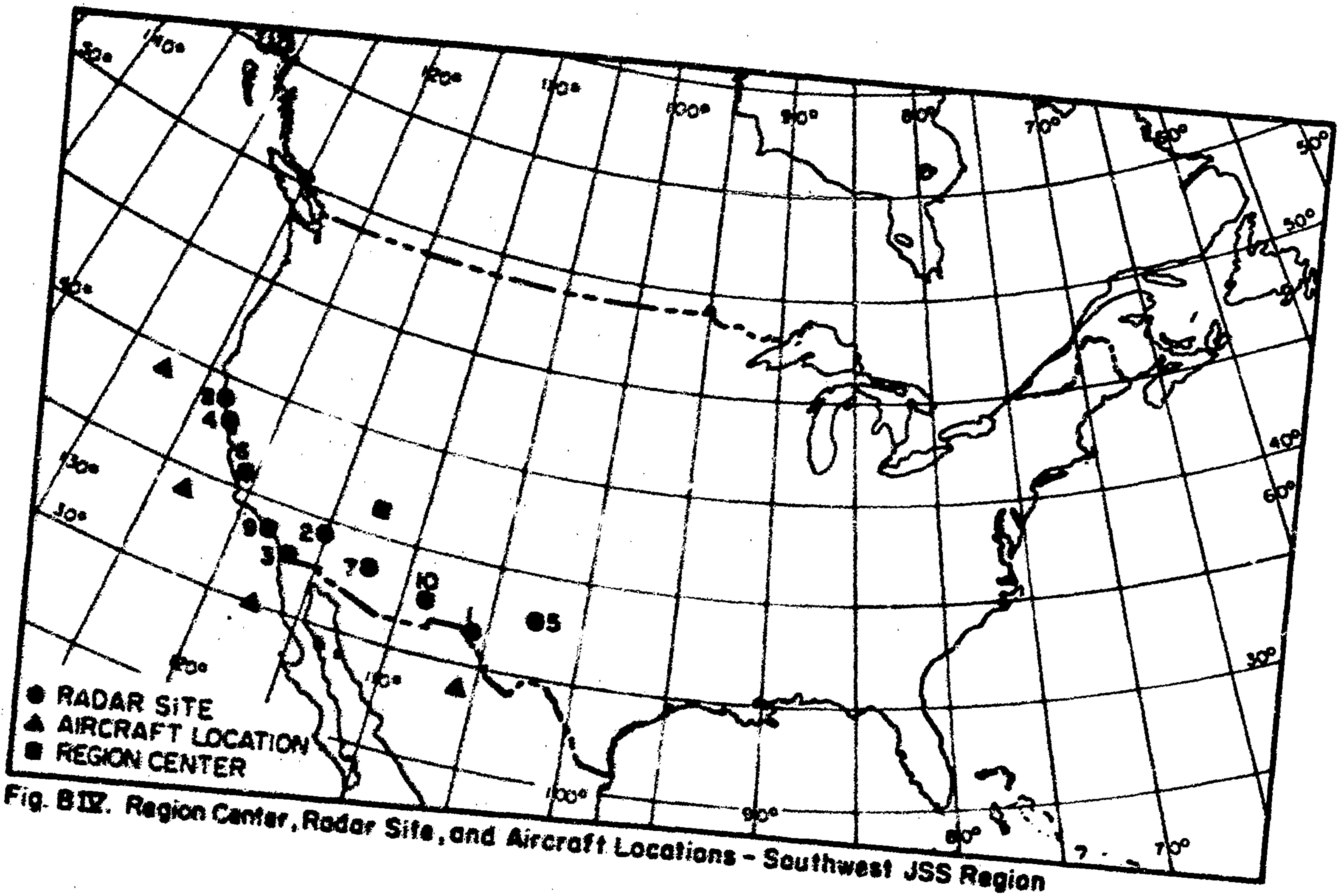


Fig. B IV. Region Center, Radar Site, and Aircraft Locations - Southwest JSS Region

TABLE XXII

REGISTRATION ERRORS — SOUTHWEST JSS REGION

| CASE # | STEREOGRAPHIC GROUND RANGE | | COORDINATES ON THE COMMON PLANE | | | | | | REGISTRATION ERROR (NM) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | BUIC/SAGE | | JSS | | ACTUAL | | | |
| | BUIC/SAGE | JSS | X | Y | X | Y | X | Y | BUIC/SAGE | JSS |
| 1 | 177.861 | 177.313 | -690.500 | 215.948 | -689.953 | 215.854 | -690.100 | 215.864 | .408 | .148 |
| 2 | 177.925 | 177.376 | -690.563 | 215.959 | -690.016 | 215.865 | -690.100 | 215.864 | .472 | .084 |
| 3a<br>3b | 177.989<br>229.341 | 177.639<br>228.622 | -690.626<br>-690.685 | 215.970<br>216.136 | -690.079<br>-690.015 | 215.875<br>215.856 | -690.100 | 215.864 | .536<br>.645 | .026<br>.086 |
| 4 | 178.955 | 178.373 | -522.635 | -110.098 | -522.167 | -109.749 | -522.270 | -109.837 | .449 | .136 |
| 5 | 179.019 | 178.437 | -522.686 | -110.137 | -522.218 | -109.788 | -522.270 | -109.837 | .514 | .072 |
| 6a<br>6b<br>6c | 179.083<br>240.458<br>245.002 | 178.501<br>239.763<br>244.176 | -522.738<br>-522.399<br>-522.991 | -110.176<br>-110.525<br>-109.715 | -522.269<br>-522.260<br>-522.168 | -109.026<br>-109.780<br>-109.823 | -522.270 | -109.837 | .578<br>.700<br>.732 | .011<br>.058<br>.102 |
| 7 | 180.327 | 179.710 | -260.577 | -370.620 | -260.324 | -370.055 | -260.374 | -370.179 | .485 | .134 |
| 8 | 180.392 | 179.774 | -260.603 | -370.680 | -260.350 | -370.114 | -260.374 | -370.179 | .550 | .070 |
| 9a<br>9b | 180.652<br>229.589 | 179.839<br>228.815 | -260.630<br>-260.311 | -370.739<br>-370.905 | -260.376<br>-260.376 | -370.173<br>-370.132 | -260.374 | -370.179 | .615<br>.729 | .007<br>.047 |
| 10 | 179.548 | 178.924 | 353.489 | -437.591 | 353.467 | -436.963 | 353.471 | -437.094 | .497 | .131 |
| 11 | 179.612 | 178.988 | 353.491 | -437.655 | 353.469 | -437.028 | 353.471 | -437.094 | .562 | .066 |
| 12 | 179.677 | 179.052 | 353.493 | -437.721 | 353.471 | -437.092 | 353.471 | -437.094 | .627 | .002 |

TABLE EXIII

SITE DATA - EASTERN CANADIAN JSS REGION

| SITE # | SITE LOCATION | | | EARTH RADIUS TO SITE | COORDINATES ON THE COMMON PLANE | |
|---|---|---|---|---|---|---|
| | DESIGNATION | APPROXIMATE LATITUDE | APPROXIMATE LONGITUDE | $E_s$ | X | Y |
| C-1 | BEAUSEJOUR, MAN | 50.1 | 96.4 | 3437.253 | -760.697 | -9.238 |
| C-2 | GYPSUMVILLE, MAN | 51.8 | 99.0 | 3436.916 | -826.242 | 117.662 |
| C-3 | MONT APICA, QUE | 48.0 | 71.8 | 3437.674 | 184.088 | -232.865 |
| C-4 | LAC ST DENIS, QUE | 46.0 | 75.0 | 3438.078 | 58.260 | -357.336 |
| C-5 | ST MARGARETS, NB | 47.0 | 65.5 | 3437.876 | 444.046 | -266.025 |
| C-6 | SENNETERRE, QUE | 48.3 | 77.8 | 3437.614 | -55.714 | -220.102 |
| C-7 | FALCONBRIDGE, ONT | 46.2 | 81.0 | 3438.038 | -190.642 | -340.154 |
| C-8 | SIOUX LOOKOUT, ONT | 50.2 | 91.9 | 3437.233 | -590.264 | -44.966 |
| C-9 | GOOSE BAY, LABR | 53.6 | 60.2 | 3436.564 | 571.518 | 160.071 |
| C-10 | GANDER, NFLD | 49.0 | 54.8 | 3437.473 | 839.591 | -55.588 |
| C-11 | MOISIE, QUE | 50.5 | 66.5 | 3437.173 | 375.718 | -64.125 |
| C-12 | SYDNEY, NS | 46.2 | 60.2 | 3438.038 | 668.436 | -274.142 |
| C-13 | CHIBOUGAMAU, QUE | 50.0 | 74.8 | 3437.273 | 61.488 | -118.584 |
| C-14 | BARRINGTON, NS | 43.5 | 65.8 | 3438.584 | 460.927 | -475.666 |
| C-15 | LOWTHER, ONT | 49.5 | 83.1 | 3437.373 | -259.965 | -137.306 |
| C-16 | REGION CENTER | 52.0 | 76.4 | - | 0.000 | 0.000 |
| RADIUS OF THE CONFORMAL SPHERE = 3411.221 | | | | | | |

TABLE BXIV

SIMULATED RADAR DATA - EASTERN CANADIAN JSS REGION

| CASE # | AIRCRAFT LOCATION | | ALTITUDE (K-FT) | REPORTING RADAR(S) | SLANT RANGE (NM) | AZIMUTH |
|---|---|---|---|---|---|---|
| | LATITUDE | LONGITUDE | | | | |
| 1 | 55.0 | 55.7 | 30 | GOOSE BAY, LABR | 179.313 | 60.176 |
| 2 | 55.0 | 55.7 | 45 | GOOSE BAY, LABR | 179.462 | 60.176 |
| 3 | 55.0 | 55.7 | 60 | GOOSE BAY, LABR | 179.644 | 60.176 |
| 4 | 52.4 | 72.0 | 30 | CHIBOUGAMAU, QUE | 178.906 | 35.157 |
| 5 | 52.4 | 72.0 | 45 | CHIBOUGAMAU, QUE | 179.055 | 35.157 |
| 6a<br>6b | 52.4 | 72.0 | 60 | CHIBOUGAMAU, QUE<br>MOISIE, QUE | 179.238<br>236.318 | 35.157<br>301.069 |
| 7 | 54.0 | 95.7 | 30 | GYPSUMVILLE, MAN | 178.618 | 40.902 |
| 8 | 54.0 | 95.7 | 45 | GYPSUMVILLE, MAN | 178.767 | 40.902 |
| 9a<br>9b | 54.0 | 95.7 | 60 | GYPSUMVILLE, MAN<br>BEAUSEJOUR, MAN | 178.950<br>236.246 | 40.902<br>6.039 |
| 10 | 42.0 | 62.3 | 30 | BARRINGTON, NS | 179.143 | 118.982 |
| 11 | 42.0 | 62.3 | 45 | BARRINGTON, NS | 179.292 | 118.982 |
| 12 | 42.0 | 62.3 | 60 | BARRINGTON, NS | 179.475 | 118.982 |

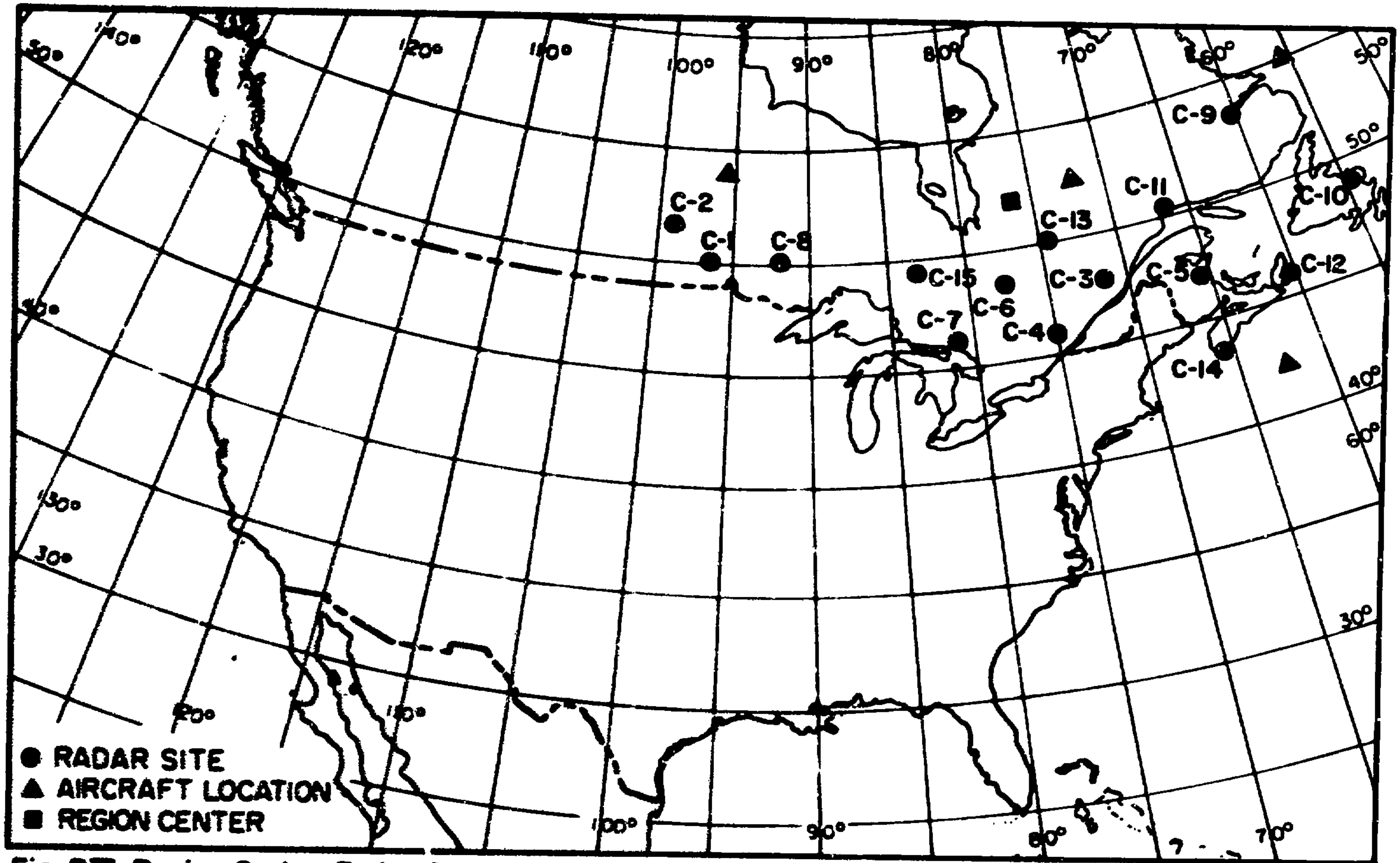


Fig. BV. Region Center, Radar Site, and Aircraft Locations – Eastern Canadian JSS Region

TABLE BXV

REGISTRATION ERRORS - EASTERN CANADIAN JSS REGION

| CASE # | STEREOGRAHPIC GROUND RANGE | | COORDINATES ON THE COMMON PLANE | | | | | | REGISTRATION ERROR (NM) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | BUIC/SAGE | | JSS | | ACTUAL | | | |
| | BUIC/SAGE | JSS | X | Y | X | Y | X | Y | BUIC/SAGE | JSS |
| 1 | 179.030 | 177.711 | 704.166 | 282.853 | 703.188 | 281.946 | 703.310 | 282.041 | 1.180 | 0.155 |
| 2 | 179.094 | 177.774 | 704.213 | 282.897 | 703.235 | 281.990 | 703.210 | 282.041 | 1.244 | 0.091 |
| 3 | 179.158 | 177.838 | 704.261 | 282.941 | 703.282 | 282.034 | 703.210 | 282.041 | 1.309 | 0.029 |
| 4 | 178.623 | 177.271 | 161.103 | 29.712 | 160.350 | 28.590 | 160.445 | 28.713 | 1.197 | 0.155 |
| 5 | 178.687 | 177.335 | 161.139 | 29.766 | 160.385 | 28.643 | 160.445 | 28.713 | 1.261 | 0.092 |
| 6a<br>6b | 178.751<br>235.828 | 177.398<br>234.049 | 161.174<br>158.910 | 29.819<br>29.401 | 160.420<br>160.543 | 28.695<br>28.698 | 160.445 | 28.713 | 1.325<br>1.682 | 0.030<br>0.099 |
| 7 | 178.335 | 177.004 | -671.725 | 211.072 | -672.877 | 210.378 | -672.738 | 210.450 | 1.189 | 0.157 |
| 8 | 178.399 | 177.067 | -671.670 | 211.105 | -672.823 | 210.412 | -672.738 | 210.450 | 1.253 | 0.093 |
| 9a<br>9b | 178.463<br>235.756 | 177.130<br>233.973 | -671.615<br>-672.103 | 211.138<br>212.024 | -672.768<br>-672.778 | 210.444<br>210.355 | -672.738 | 210.450 | 1.318<br>1.697 | 0.030<br>0.103 |
| 10 | 178.860 | 177.438 | 629.795 | -540.713 | 628.449 | -540.196 | 628.575 | -540.256 | 1.303 | 0.139 |
| 11 | 178.924 | 177.502 | 629.855 | -540.737 | 628.509 | -540.220 | 628.575 | -540.256 | 1.368 | 0.075 |
| 12 | 178.988 | 177.565 | 629.916 | -540.760 | 628.569 | -540.243 | 628.575 | -540.256 | 1.433 | 0.015 |

TABLE BXVI

SITE DATA — WESTERN CANADIAN JSS REGION

| SITE # | SITE LOCATION | | | EARTH RADIUS TO SITE | COORDINATES ON THE COMMON PLANE | |
|---|---|---|---|---|---|---|
| | | APPROXIMATE | | | | |
| | DESIGNATION | LATITUDE | LONGITUDE | $E_s$ | X | Y |
| C-1 | BEAUSEJOUR, MAN | 50.1 | 96.4 | 3437.253 | 601.258 | 4.049 |
| C-2 | HOLBERG, BC | 50.7 | 128.0 | 3437.133 | -601.122 | 41.035 |
| C-3 | BALDY HUGHES, BC | 53.8 | 122.8 | 3436.525 | -378.533 | 189.690 |
| C-4 | BEAVERLODGE, ALTA | 55.2 | 119.2 | 3436.256 | -243.268 | 257.619 |
| C-5 | COLD LAKE, ALTA | 54.2 | 110.5 | 3436.448 | 56.215 | 186.238 |
| C-6 | GYPSUMVILLE, MAN | 51.8 | 99.0 | 3436.916 | 484.381 | 85.274 |
| C-7 | YORKTON, SASK | 51.2 | 102.8 | 3437.034 | 349.035 | 28.033 |
| C-8 | DANA, SASK | 52.0 | 105.9 | 3436.876 | 228.883 | 63.544 |
| C-9 | ALASKA, SASK | 51.2 | 109.9 | 3437.034 | 82.707 | 7.216 |
| C-10 | PENHOLD, ALTA | 51.9 | 114.0 | 3436.896 | -70.348 | 48.789 |
| C-11 | KAMLOOPS, BC | 50.8 | 120.1 | 3437.114 | -302.978 | -1.543 |
| C-12 | REGION CENTER | 51.1 | 112.1 | - | 0.000 | 0.000 |

RADIUS OF THE CONFORMAL SPHERE = 3423.829

TABLE XXVII

SIMULATED RADAR DATA - WESTERN CANADIAN JSS REGION

| CASE # | AIRCRAFT LOCATION LATITUDE | AIRCRAFT LOCATION LONGITUDE | ALTITUDE (K-FT) | REPORTING RADAR(S) | SLANT RANGE (NM) | AZIMUTH |
|---|---|---|---|---|---|---|
| 1 | 51.0 | 132.7 | 30 | HOLBERG, BC | 179.783 | 277.577 |
| 2 | 51.0 | 132.7 | 45 | HOLBERG, BC | 179.931 | 277.577 |
| 3 | 51.0 | 132.7 | 60 | HOLBERG, BC | 180.114 | 277.577 |
| 4 | 57.0 | 123.5 | 30 | BEAVERLODGE, ALTA | 180.652 | 308.603 |
| 5a<br>5b | 57.0 | 123.5 | 45 | BEAVERLODGE, ALTA<br>BALDY HUGHES, BC | 180.801<br>194.178 | 308.603<br>353.191 |
| 6a<br>6b | 57.0 | 123.5 | 60 | BEAVERLODGE, ALTA<br>BALDY, HUGHES, BC | 180.983<br>194.357 | 308.603<br>353.191 |
| 7 | 57.0 | 108.6 | 30 | COLD LAKE, ALTA | 180.485 | 20.236 |
| 8 | 57.0 | 108.6 | 45 | COLD LAKE, ALTA | 180.634 | 20.236 |
| 9 | 57.0 | 108.6 | 60 | COLD LAKE, ALTA | 180.816 | 20.236 |
| 10 | 52.0 | 92.7 | 30 | BEAUSEJOUR, MAN | 180.843 | 49.402 |
| 11 | 52.0 | 92.7 | 45 | BEAUSEJOUR, MAN | 180.991 | 49.402 |
| 12a<br>12b | 52.0 | 92.7 | 60 | BEAUSEJOUR, MAN<br>GYPSUMVILLE, MAN | 181.173<br>234.886 | 49.402<br>84.586 |

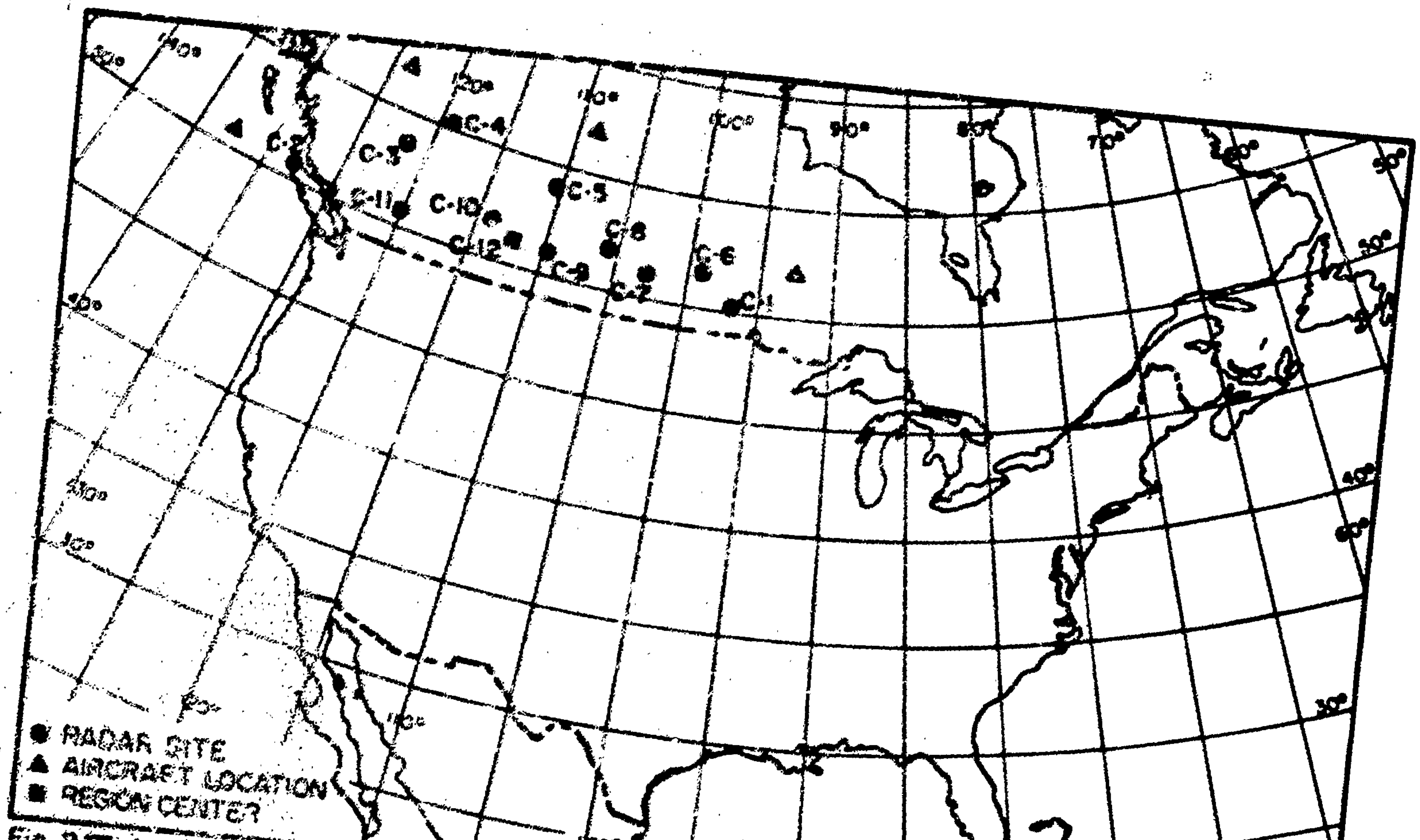


Fig. B XI. Region Center, Radar Site and Aircraft Locations - Western Canadian JSS Region

TABLE XXVIII

REGISTRATION ERRORS - WESTERN CANADIAN JSS REGION

| CASE # | STEREOGRAPHIC GROUND RANGE | | COORDINATES ON THE COMMON PLANE | | | | | | REGISTRATION ERROR (NM) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | BUIC/SAGE | | JSS | | ACTUAL | | | |
| | BUIC/SAGE | JSS | X | Y | X | Y | X | Y | BUIC/SAGE | JSS |
| 1 | 179.350 | 178.854 | -771.512 | 102.895 | -770.872 | 102.655 | -771.020 | 102.692 | .551 | .152 |
| 2 | 179.364 | 178.876 | -771.391 | 102.917 | -770.933 | 102.677 | -771.020 | 102.692 | .616 | .088 |
| 3 | 179.628 | 178.934 | -771.654 | 102.939 | -770.994 | 102.699 | -771.020 | 102.692 | .681 | .027 |
| 4 | 180.369 | 179.217 | -372.917 | 384.040 | -372.468 | 383.583 | -372.591 | 383.682 | .498 | .158 |
| 5a<br>5b | 180.431<br>191.975 | 179.741<br>191.049 | -372.994<br>-372.450 | 384.085<br>384.288 | -372.515<br>-372.593 | 383.628<br>383.569 | -372.591 | 383.682 | .563<br>.606 | .094<br>.113 |
| 6a<br>6b | 180.497<br>191.876 | 179.845<br>191.258 | -373.019<br>-372.567 | 384.130<br>384.352 | -372.561<br>-372.598 | 383.673<br>383.638 | -372.591 | 383.682 | .627<br>.675 | .032<br>.044 |
| 7 | 140.202 | 179.741 | 114.441 | 356.919 | 114.665 | 356.293 | 114.724 | 356.442 | .503 | .160 |
| 8 | 140.264 | 179.603 | 114.902 | 356.980 | 114.686 | 356.354 | 114.724 | 356.442 | .567 | .096 |
| 9 | 140.318 | 179.669 | 114.922 | 357.041 | 114.707 | 356.414 | 114.724 | 356.442 | .632 | .032 |
| 10 | 140.559 | 179.925 | 711.318 | 149.246 | 710.909 | 148.678 | 711.015 | 148.796 | .554 | .158 |
| 11 | 140.624 | 179.919 | 711.372 | 149.299 | 710.944 | 148.730 | 711.015 | 148.796 | .619 | .094 |
| 12a<br>12b | 140.624<br>216.397 | 179.981<br>211.506 | 711.416<br>711.291 | 149.350<br>149.042 | 710.987<br>710.926 | 148.782<br>148.799 | 711.015 | 148.796 | .684 | .031 |

TABLE BXIX

SITE DATA - ALASKAN JSS REGION

| SITE # | SITE LOCATION | | | EARTH RADIUS TO SITE | COORDINATES ON THE COMMON PLANE | |
|---|---|---|---|---|---|---|
| | DESIGNATION | APPROXIMATE LATITUDE | APPROXIMATE LONGITUDE | $E_s$ | X | Y |
| 1 | CAPE LISBURNE | 68.9 | 166.1 | 3433.972 | -158.347 | 406.203 |
| 2 | TIN CITY | 65.6 | 168.0 | 3434.451 | -228.125 | 214.751 |
| 3 | KOTZEBUE | 66.9 | 162.6 | 3434.256 | -89.796 | 279.180 |
| 4 | INDIAN MT | 66.1 | 153.7 | 3434.375 | 124.323 | 233.333 |
| 5 | CAMPION | 64.7 | 156.7 | 3434.590 | 53.998 | 145.056 |
| 6 | FORT YUKON | 66.6 | 145.2 | 3434.300 | 323.211 | 293.186 |
| 7 | MURPHY DOME | 65.0 | 148.4 | 3434.543 | 263.517 | 183.669 |
| 8 | TATILINA | 62.9 | 156.0 | 3434.880 | 76.693 | 37.692 |
| 9 | SPARREVON | 61.1 | 155.6 | 3435.184 | 92.970 | -69.769 |
| 10 | FIRE ISLAND | 61.2 | 150.2 | 3435.167 | 248.535 | -49.613 |
| 11 | KING SALMON | 58.7 | 156.7 | 3435.607 | 65.641 | -215.123 |
| 12 | COLD BAY | 55.3 | 162.9 | 3436.237 | -140.719 | -416.257 |
| 13 | CAPE ROMANZOF | 61.8 | 166.0 | 3435.064 | -204.248 | -18.689 |
| 14 | CAPE NEWENHAM | 58.6 | 162.1 | 3435.625 | -103.432 | -219.587 |
| 15 | REGION CENTER | 62.3 | 158.8 | - | 0.000 | 0.000 |
| RADIUS OF THE CONFORMAL SPHERE = 3427.488 | | | | | | |

TABLE BXX

SIMULATED RADAR DATA – ALASKAN JSS REGION

| CASE # | AIRCRAFT LOCATION LATITUDE | AIRCRAFT LOCATION LONGITUDE | ALTITUDE (K-FT) | REPORTING RADAR(S) | SLANT RANGE (NM) | AZIMUTH |
|---|---|---|---|---|---|---|
| 1 | 71.9 | 165.0 | 30 | CAPE LISBURNE | 182.265 | 6.500 |
| 2 | 71.9 | 165.0 | 45 | CAPE LISBURNE | 182.413 | 6.500 |
| 3 | 71.9 | 165.0 | 60 | CAPE LISBURNE | 182.595 | 6.500 |
| 4 | 64.0 | 174.0 | 30 | TIN CITY | 181.697 | 240.712 |
| 5 | 64.0 | 174.0 | 45 | TIN CITY | 181.845 | 240.712 |
| 6 | 64.0 | 174.0 | 60 | TIN CITY | 182.027 | 240.712 |
| 7 | 56.0 | 168.1 | 30 | COLD BAY | 181.840 | 285.529 |
| 8 | 56.0 | 168.1 | 45 | COLD BAY | 181.989 | 285.529 |
| 9 | 56.0 | 168.1 | 60 | COLD BAY | 182.171 | 285.529 |
| 10 | 58.2 | 150.0 | 30 | FIRE ISLAND | 180.750 | 177.983 |
| 11a<br>11b | 58.2 | 150.0 | 45 | FIRE ISLAND<br>KING SALMON | 180.899<br>213.608 | 177.983<br>95.237 |
| 12a<br>12b<br>12c | 58.2 | 150.0 | 60 | FIRE ISLAND<br>KING SALMON<br>SPARREVON | 181.081<br>213.784<br>244.284 | 177.983<br>95.237<br>133.211 |

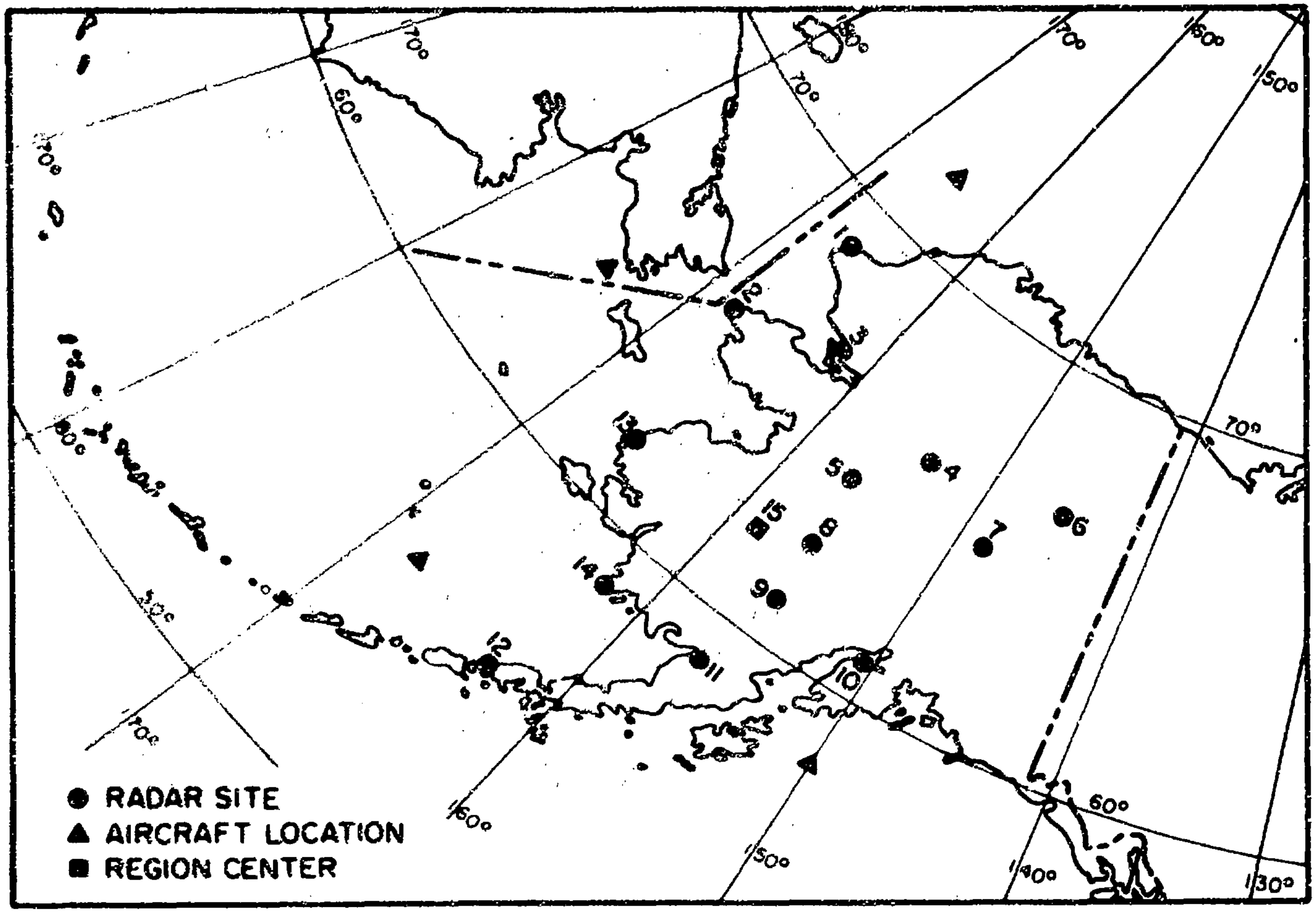


Fig. B VIII. Region Center, Radar Site, and Aircraft Locations - Alaskan JSS Region

TABLE BXXI

REGISTRATION ERRORS - ALASKAN JSS REGION

| CASE # | STEREOGRAPHIC GROUND RANGE | | COORDINATES ON THE COMMON PLANE | | | | | | REGISTRATION ERROR (NM) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | BUIC/SAGE | | JSS | | ACTUAL | | | |
| | BUIC/SAGE | JSS | X | Y | X | Y | X | Y | BUIC/SAGE | JSS |
| 1 | 181.980 | 181.637 | -116.542 | 584.333 | -116.621 | 583.997 | -116.582 | 584.149 | .189 | .157 |
| 2 | 182.045 | 181.702 | -116.527 | 584.397 | -116.606 | 584.061 | -116.582 | 584.149 | .254 | .091 |
| 3 | 182.110 | 181.767 | -116.512 | 584.461 | -116.591 | 584.124 | -116.582 | 584.149 | .320 | .026 |
| 4 | 181.413 | 181.045 | -397.830 | 149.306 | -397.487 | 149.439 | -397.618 | 149.379 | .224 | .145 |
| 5 | 181.477 | 181.110 | -397.891 | 149.282 | -397.547 | 149.415 | -397.618 | 149.379 | .289 | .080 |
| 6 | 181.542 | 181.174 | -397.951 | 149.259 | -397.607 | 149.392 | -397.618 | 149.379 | .354 | .017 |
| 7 | 181.556 | 181.094 | -312.948 | -356.503 | -312.511 | -356.656 | -312.662 | -356.620 | .309 | .156 |
| 8 | 181.621 | 181.159 | -313.010 | -356.482 | -312.572 | -356.635 | -312.662 | -356.620 | .374 | .091 |
| 9 | 181.686 | 181.224 | -313.071 | -356.460 | -312.633 | -356.613 | -312.662 | -356.620 | .439 | .030 |
| 10 | 180.467 | 180.064 | 278.472 | -227.893 | 278.405 | -227.495 | 278.426 | -227.623 | .274 | .129 |
| 11a<br>11b | 180.532<br>213.225 | 180.129<br>212.722 | 278.483<br>278.805 | -227.957<br>-227.626 | 278.416<br>278.301 | -227.559<br>-227.597 | 278.426 | -227.623 | .339<br>.379 | .065<br>.127 |
| 12a<br>12b<br>12c | 180.596<br>213.301<br>243.793 | 180.193<br>212.797<br>243.247 | 278.493<br>278.881<br>278.794 | -228.021<br>-227.630<br>-227.917 | 278.427<br>278.377<br>278.377 | -227.622<br>-227.601<br>-227.563 | 278.426 | -227.623 | .404<br>.455<br>.471 | .001<br>.053<br>.077 |